91602
new 82-10

LEGAL NOTICE

This report was prepared by Ontario Hydro and, while effort has been made to assure the accuracy and applicability of the material contained herein, neither Ontario Hydro nor any person acting on its behalf:

(a) makes any warranty, or representation with respect to the accuracy of any data, apparatus, method or process disclosed in this report or that such use may not infringe privately owned rights; or

(b) assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method or process disclosed in this report.

COMPLIMENTARY COPY
Please Credit Ontario Hydro Research if Reproduced in Whole or in Part

ontario hydro
research division

NIAGARA PUMPED STORAGE RESERVOIR DYKE MONITORING OF CORE PORE PRESSURE

Report No 91-133-K

R.H.K. Tsang
Engineer
Soil Sciences Section
Civil Research Department

ABSTRACT

Continuous monitoring of 22 hydraulic twin tube piezometers was performed at the Niagara pumping generating station reservoir dyke. In addition, the corresponding reservoir level was monitored using a sonic sensor. The data collected is presented in this report.

job	file	date	report no.
43-115-281	843.4	July 16, 1991	91-133-K

92-03503/

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
2.0	INSTALLATION OF INSTRUMENTATION	1
3.0	SUMMARY OF RESULTS	2
4.0	CONCLUSIONS	3
5.0	RECOMMENDATIONS	3
REFERENCES		4
TABLES I to II		5
FIGURES 1 - 10		7
APPENDIX A TO D		17
DISTRIBUTION		last page

ontario hydro
research division

To Mr. O. Bernaus
Manager
Civil Maintenance Department
Hydraulic Generation Group

Attn: Mr. G.F. Smith/Mr. I. Azis

NIAGARA PUMPED STORAGE RESERVOIR DYKE
MONITORING OF CORE PORE PRESSURE

1.0 INTRODUCTION

A data acquisition system was used to monitor 22 hydraulic twin tube piezometers at the Niagara pumped storage reservoir dyke, including the reservoir level. A cross-section of the piezometer locations is shown in Figure 1. Manual pressure gauge readings were taken prior to installing the electrical pressure transducers on-line for automatic monitoring (Tables I and II). These manual readings provide a "reference" pore water pressure existing in the dyke before installing the electrical transducers on-line. These manual readings are similar to those taken on January 8, 1990 by J.P. Adams of the Soil Sciences Section, Civil Research Department/1/.

The pore water pressure data and reservoir level data will be used for analysis to determine the hydrodynamic time lag and to provide pore pressure conditions for a stability analysis of the dyke. All the collected data has been made available to Dam Safety, Civil Maintenance Department in a Lotus 2.2 worksheet format.

2.0 INSTALLATION OF INSTRUMENTATION

As stated earlier, manual gauge pressure readings were taken prior to installing the electrical pore pressure transducers. (Tables I and II). By automating these pore pressure readings, continuous time correlations with the changes in the reservoir level during operations are provided.

The Quick-connect fittings and external flushing method using compressed gas facilitated the transducer installation. The external flushing pressure used was 20 psi. As a result of the external flushing, excess pore pressures were introduced into the system. Consequently,

dissipation time was required before actual changes in pore water pressures recorded were due to corresponding reservoir level changes.

The scanning frequency selected was an average reading over a 10 minute interval. The pressure transducers specifications are full scale 0-20 psi with +/- 0.1% accuracy. The power supply used was stable at 10 volts +/- 0.05 volts. A set of 6 transducers was rotated to monitor the 22 piezometers over a two week period per set. A sonic sensor was used to record the reservoir levels from the top of the dyke (nominal elevation 630.0 ft).

3.0 SUMMARY OF RESULTS

The summaries of the pore water pressures and reservoir levels are presented in Figures 2 to 5. These plots show the large excess pore pressure dissipated as a result of the external flushing (20 psi). The dissipation time required, after external flushing, for the piezometers varied from 1 to 8 days depending on the location of the piezometers. Typically, two days were required to reach 90% dissipation of the flushing pressure. As a result, the transducers were monitored over a two week period to allow for variations in the dissipation rates.

The summary plots of pore water pressure (Figures 2 to 5) do not have the resolution to show the pore water pressure changes due to operating reservoir levels. Individual plots of the pressure for each piezometer and corresponding reservoir level are provided (Appendix A and Lotus 2.2 worksheets).

Some difficulties were encountered during the monitoring phase. The following summarize these anomalies:

(a) The sonic sensor malfunctioned from March 7 to 15/91. The sensor got wet due to high winds and heavy rain. No reservoir level data was obtained.

(b) Piezometer (#P4) responded differently from the other piezometers from March 6-27/91) (Figure 2). Figure 1 from CEAD report states that P4 is a "dummy gauge".

(c) Piezometer (#P18) responded differently from April 12-26/91 (Figure 4). The piezometer malfunctioned and could not be flushed with an external pressure of 20 psi.

(d) Piezometers (#P2 and #P5) were monitored twice, March 6-26/91 and April 26 to May 10/91, due to the observed sudden jump in pore pressures (Figures 2 and 5).

Fluctuations of the reservoir water level, air temperature of the gauge house, and power supply (nominal 10 volts) are plotted in Figures 6 to 9. The gauge house was heated. The power supply was stable.

Figure 10 is a schematic of the instrumentation panel at the gauge house. The nominal floor elevation is 579.0 ft (Figure 1). The change in elevation heads can be applied to the recorded pore pressure readings.

4.0 CONCLUSIONS

Twenty-two hydraulic twin tube piezometers in the dyke core and reservoir level were monitored using an automated data acquisition system. The data was collected, plotted, and summarized in this report. Hydrodynamic time lag and pore pressure conditions can be obtained from the available data. Further pore pressure and reservoir level readings could be obtained if seasonal variations at the site are required.

5.0 RECOMMENDATIONS

1. High quality data was obtained for pore water pressures and reservoir levels showing the hydrodynamic changes with time which is applicable at this and other sites.

2. Additional electrical transducers for monitoring could have shortened the monitoring period. Currently, a total of 10-12 weeks was required with six transducers.

ACKNOWLEDGMENTS

The efforts of Mr. J.P. Adams, Soil Sciences Section, Civil Research Department are appreciated. Mr. Adams performed the installation and software development for this application.

Approved by:

J.B. Brown
Manager
Civil Research Department

Prepared by:

R.H.K. Tsang
Engineer
Soil Sciences Section

Reviewed by:

T.J. Carmichael
Supervising Engineer
Soil Sciences Section

RHKT:LM

REFERENCES

1. Adams, J.P. Memorandum to Mr. I. Azis, Dam Safety, Civil Maintenance, February 20, 1991.

TABLE I

MANUAL PIEZOMETER GAUGE READINGS TAKEN BEFORE INSTALLING PRESSURE TRANSDUCERS

SIR ADAM BECK
NIAGARA PUMPING GENERATING STATION
INTERNAL PIEZOMETER READINGS

DATE OF READINGS: MARCH 4/91

GAUGE NO	PRESSURE (psi)	GAUGE NO	PRESSURE (psi)
1L	0.0	1R	1.0
2L	1.5	2R	1.0
3L	5.5	3R	6.5
4L	4.5	4R	4.0
5L	17.0	5R	6.0
6L	7.5	6R	6.5
7L	6.0	7R	6.0
8L	3.5	8R	3.5
9L	3.0	9R	3.0
10L	6.0	10R	6.0
11L	8.5	11R	8.0
12L	10.5	12R	9.5
13L	10.5	13R	12.0
14L	6.5	14R	2.5
15L	9.0	15R	9.5
16L	12.0	16R	11.5
17L	13.5	17R	12.5
18L	7.5	18R	9.0
19L	9.0	19R	7.0
20L	14.5	20R	12.5
21L	13.5	21R	-1.0
22L	14.5	22R	12.0

TABLE II

ADDITIONAL MANUAL PIEZOMETER GAUGE READINGS TAKEN BEFORE INSTALLING PRESSURE TRANSDUCER

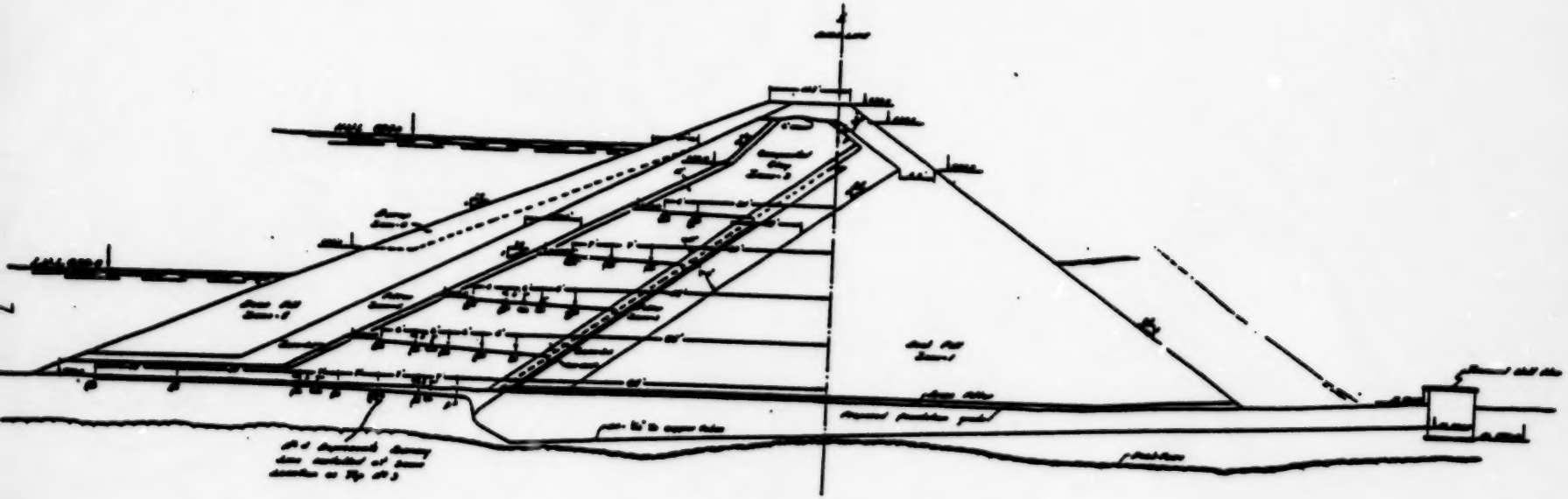
SIR ADAM BECK
NIAGARA PUMPING GENERATING STATION
INTERNAL PIEZOMETER READINGS

DATE OF READINGS: MARCH 28/91

GAUGE NO	PRESSURE (psi)	GAUGE NO	PRESSURE (psi)
1L	0.0	1R	3.5
2L	3.5	2R	8.5
3L	5.0	3R	7,0
4L	4.0	4R	3.5
5L	10.0	5R	5.0
6L	7.5	6R	7.5
7L	5.0	7R	8.0
8L	3.0	8R	3.0
9L	3.0	9R	3.0
10L	5.5	10R	6.0
11L	8.0	11R	8.0
12L	10.0	12R	10.0

DATE OF READINGS: APRIL 12/91

GAUGE NO	PRESSURE (psi)	GAUGE NO	PRESSURE (psi)
13L	10.0	13R	11.0
14L	6.0	14R	4.0
15L	8.0	15R	9.0
16L	11.0	16R	11.0
17L	15.0	17R	15.0
18L	7.0	18R	8.5



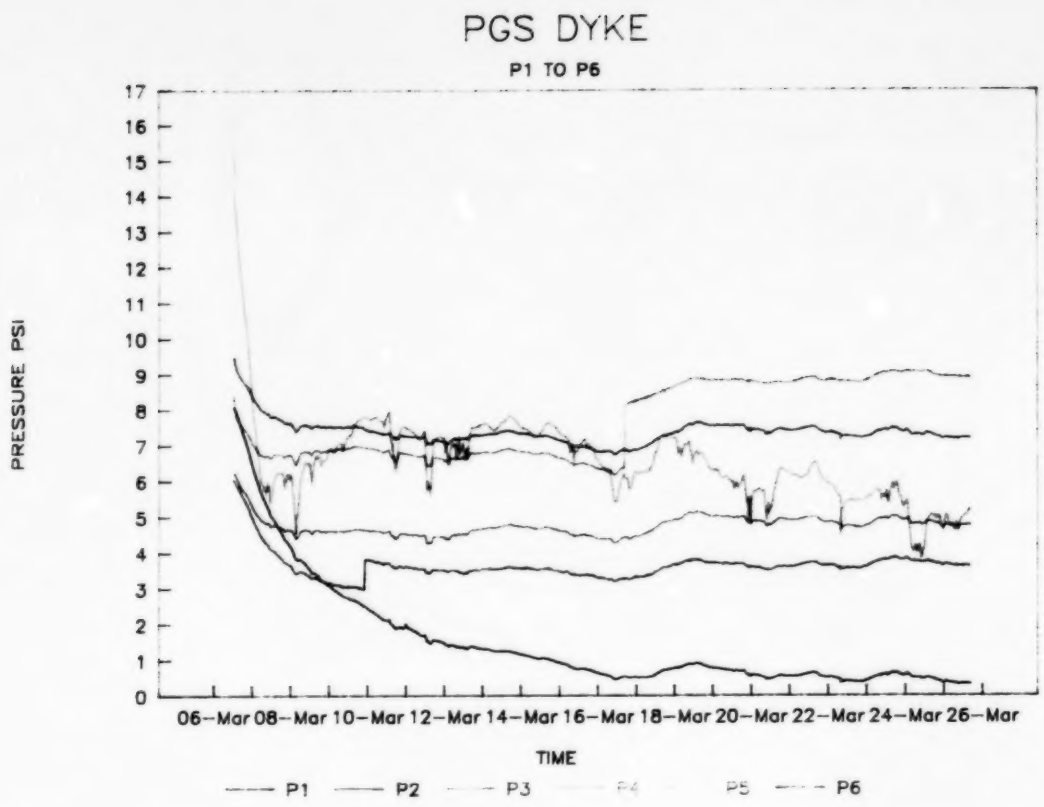
STA 247+00

design & construction branch
civil engineering & architecture dept

0 10 20 30 FEET
SCALE

PUMP STORAGE RESERVOIR DYKE
CROSS - SECTION AND
LOCATION OF PIEZOMETERS

FIGURE 1



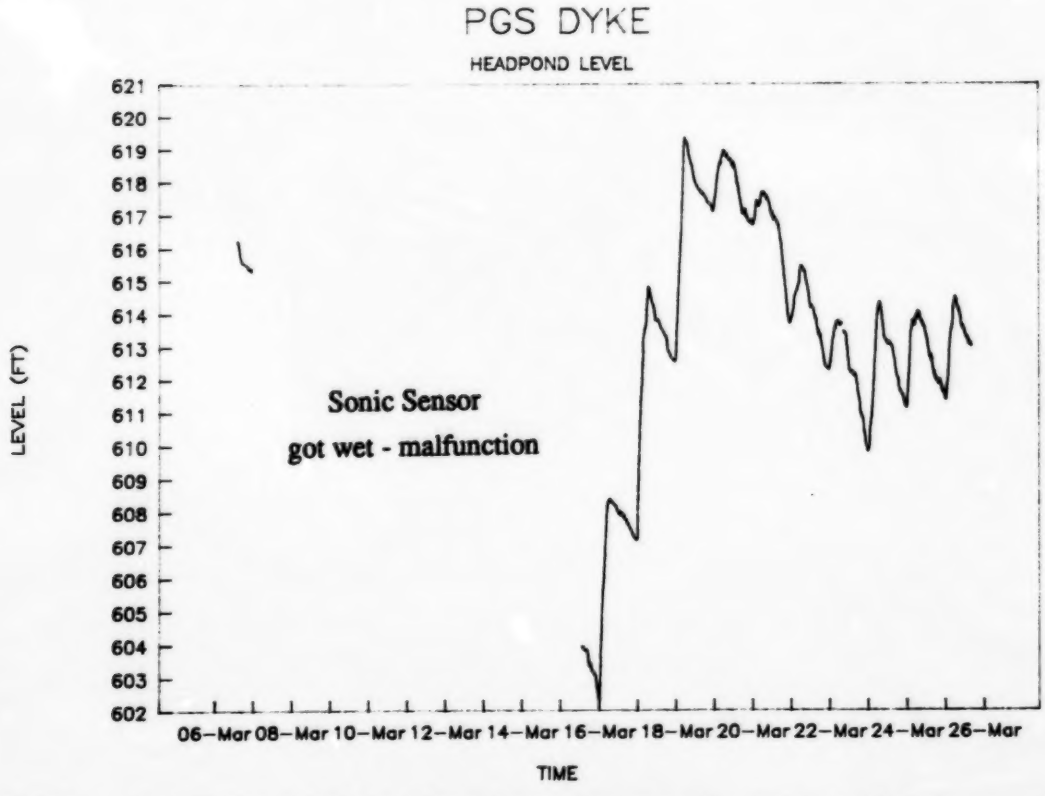
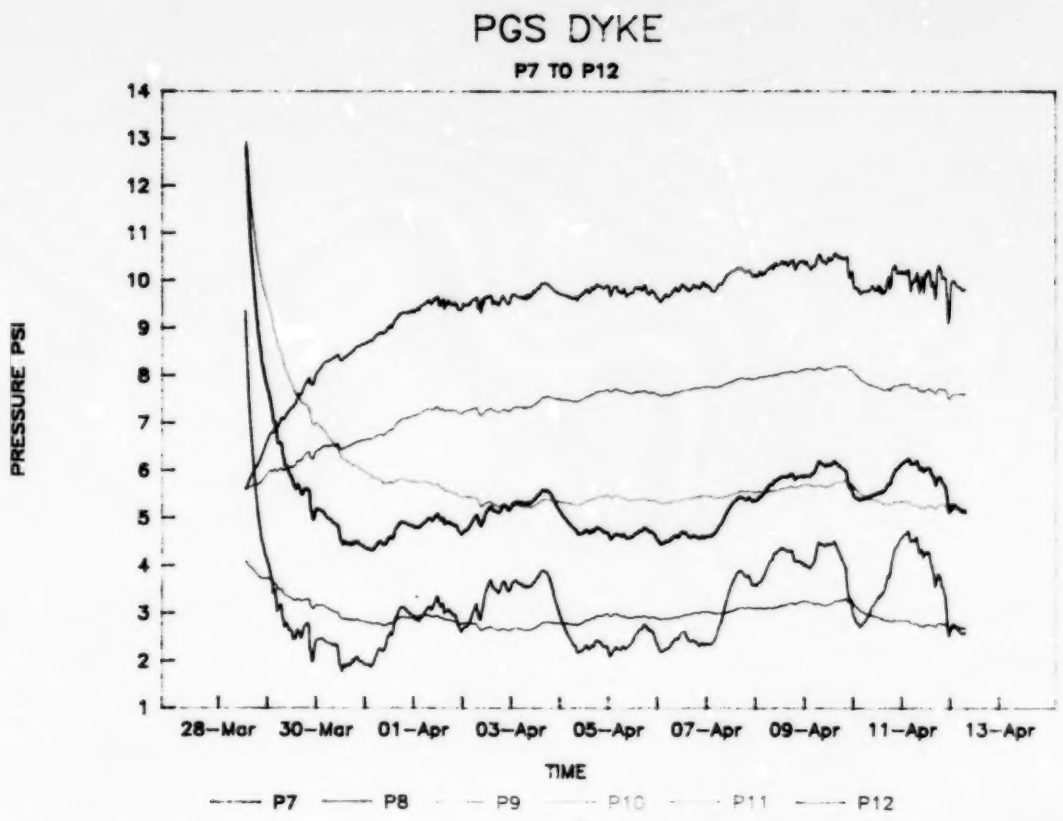


FIGURE 2: Reservoir Level and Pore Water Pressure Monitoring (Piezometers P1 to P6)



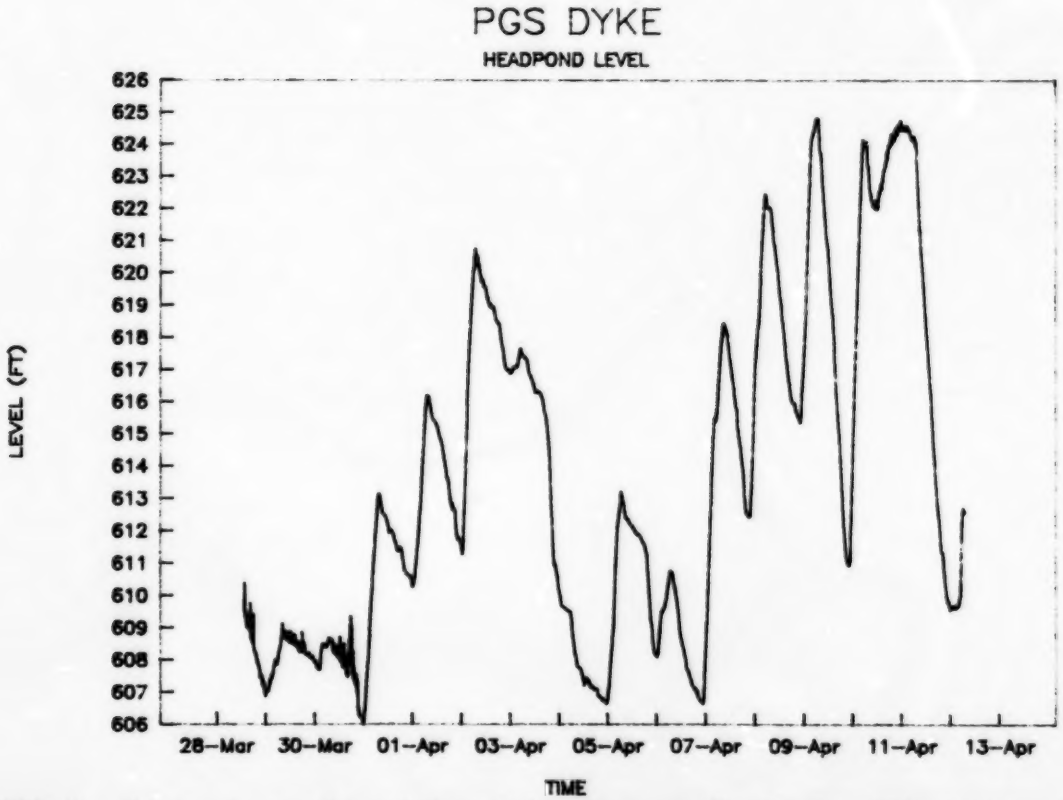
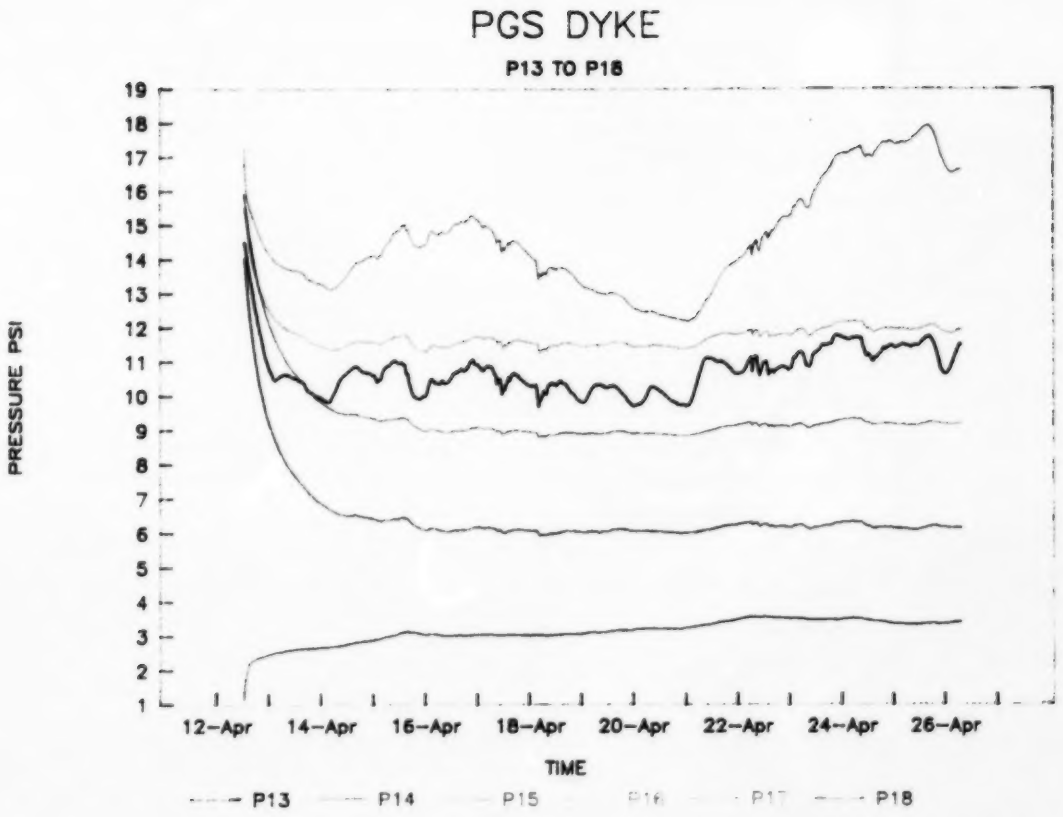


FIGURE 3: Reservoir Levels and Pore Water Pressure Monitoring (Piezometers P7 to P12



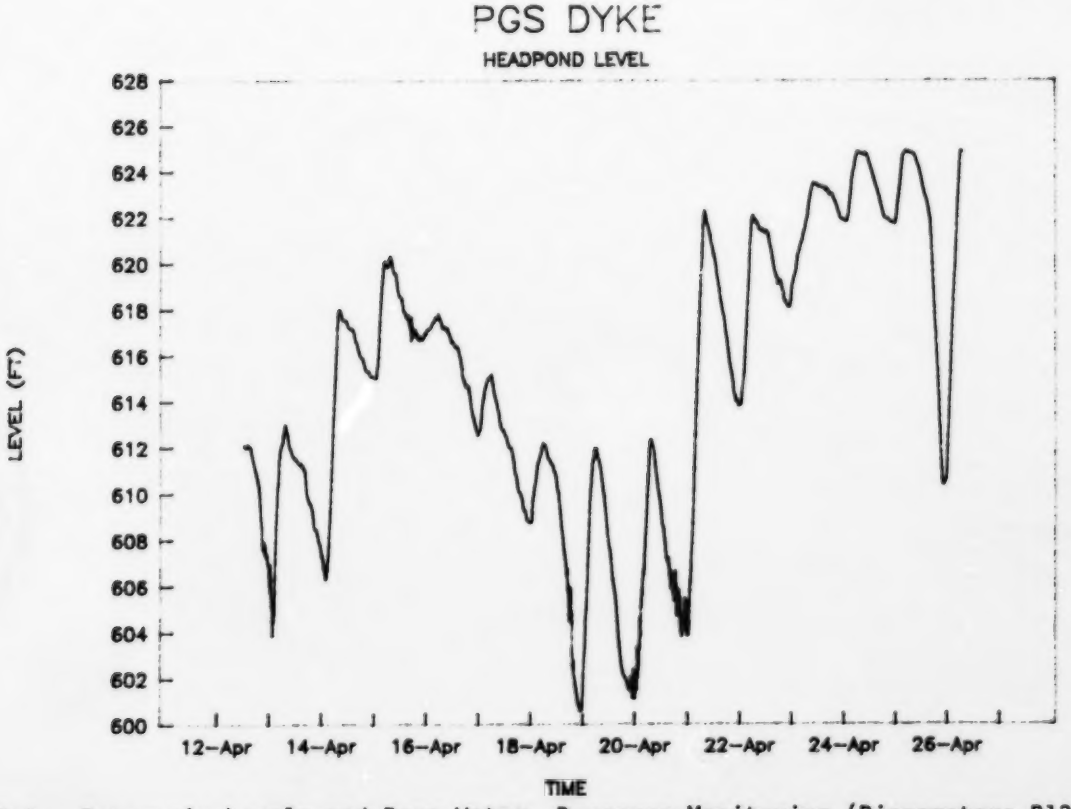
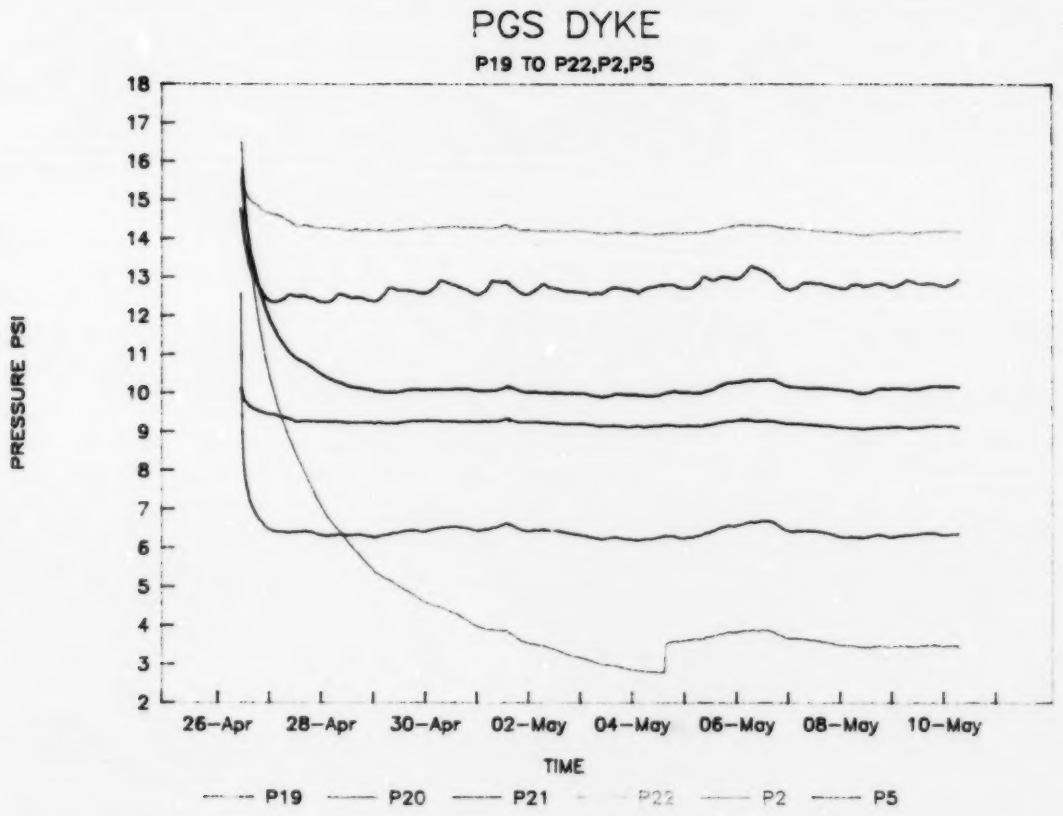


FIGURE 4: Reservoir Levels and Pore Water Pressure Monitoring (Piezometers P13 to P18)

91-133



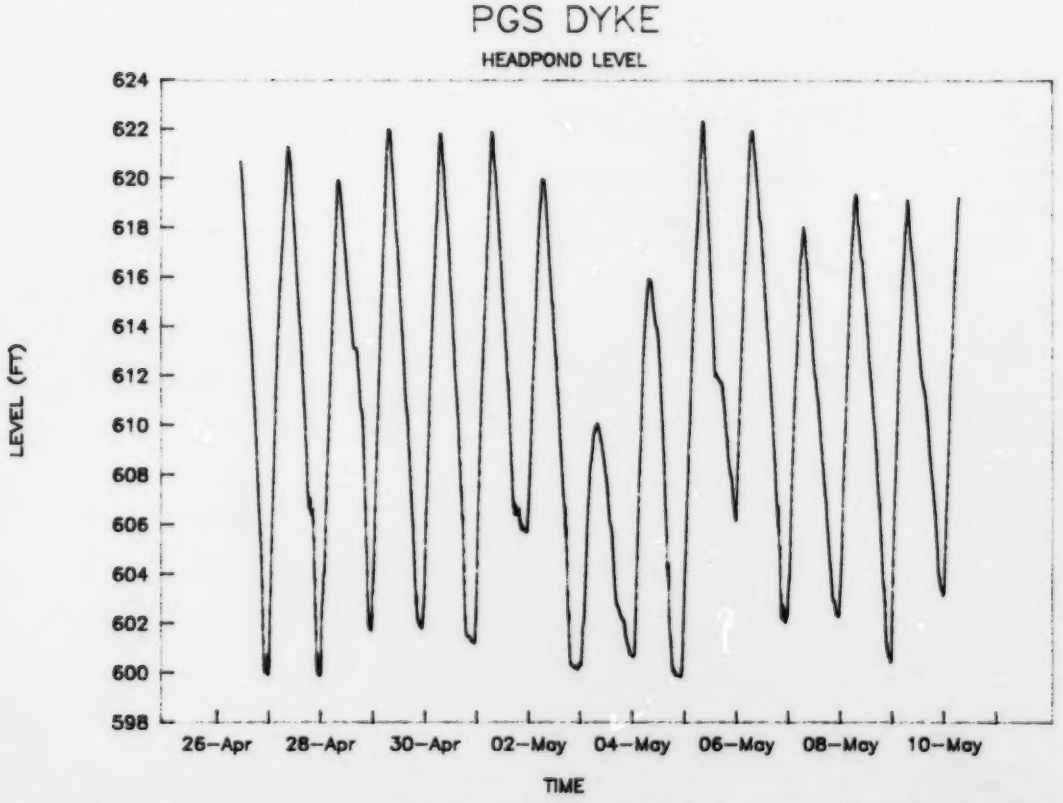
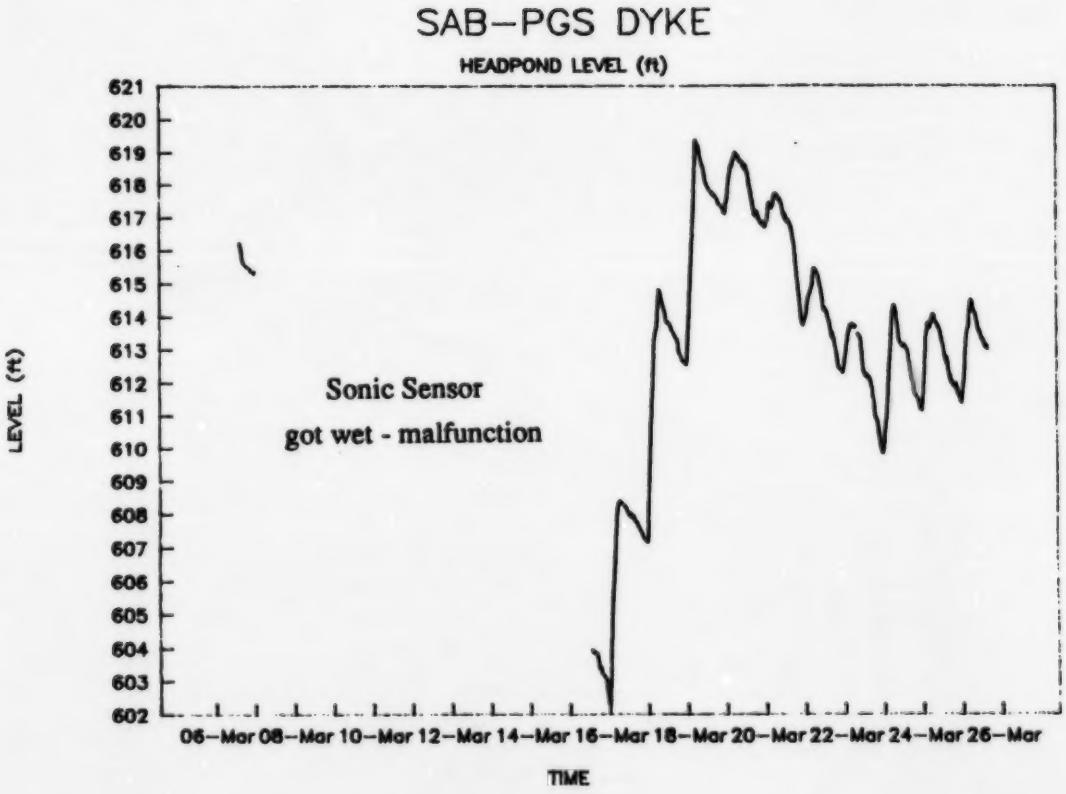


FIGURE 5: Reservoir Levels and Pore Water Pressure Monitoring (Piezometers P19 to P22 and P2 + P5)



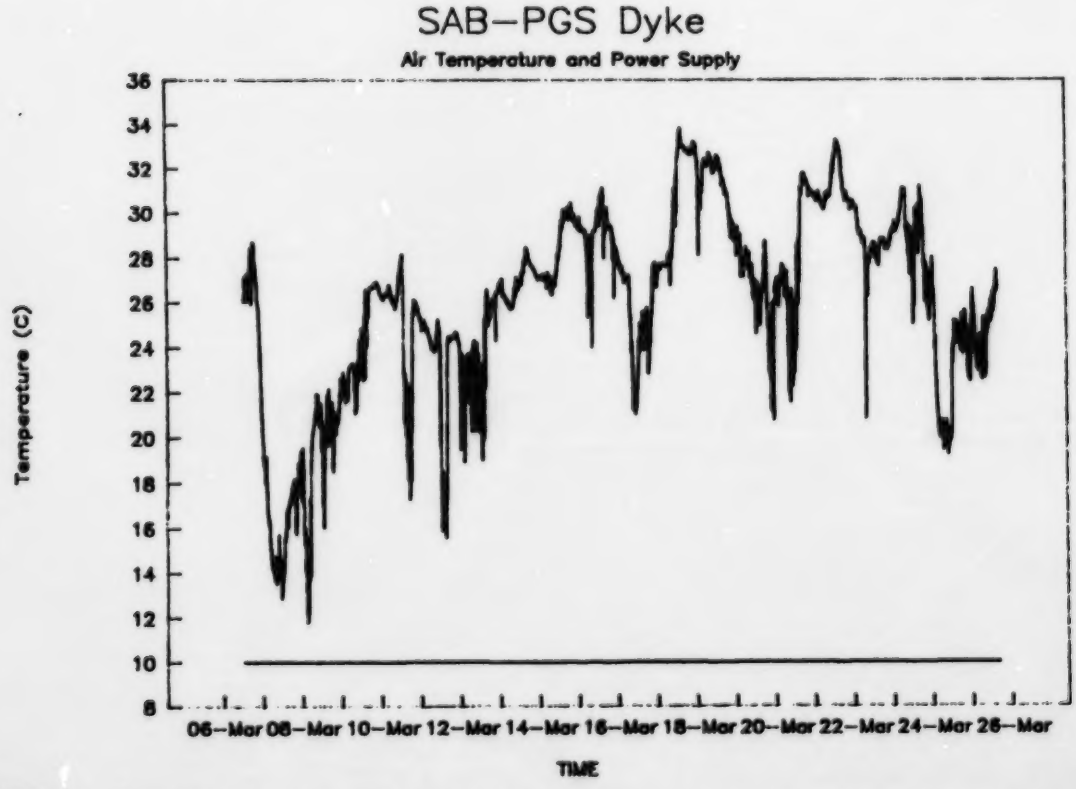
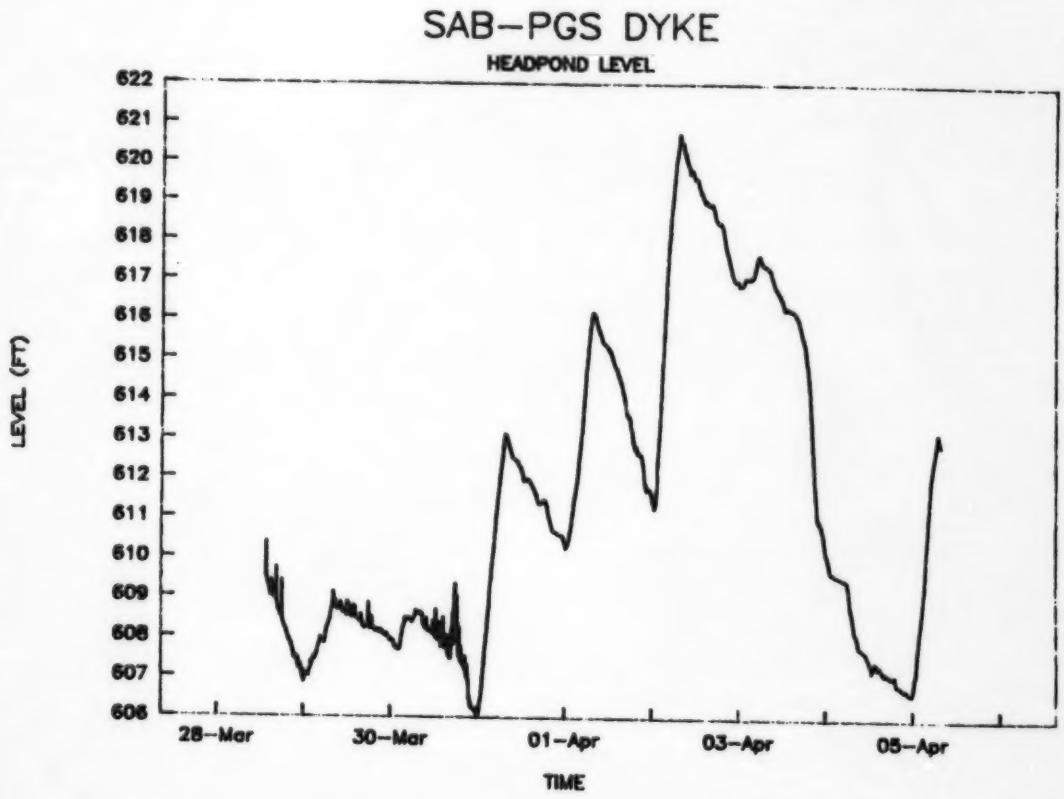


FIGURE 6: Summary of Headpond Level, Air Temperature of Gauge House, and Power Supply - March 6-27/91



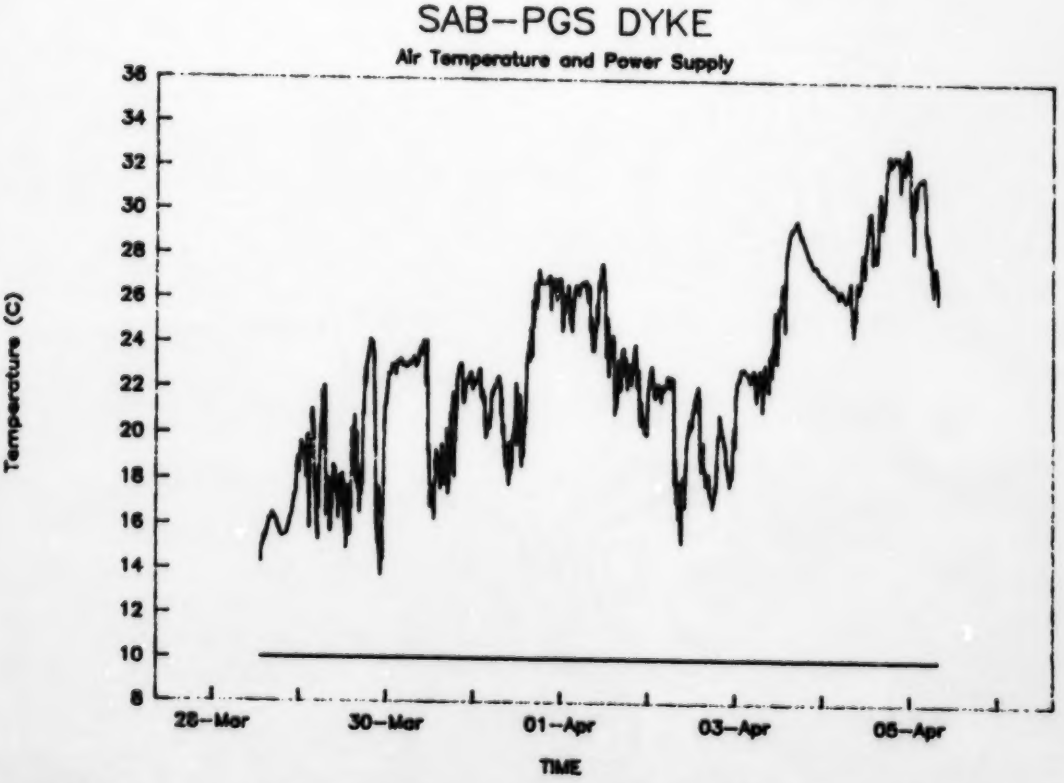
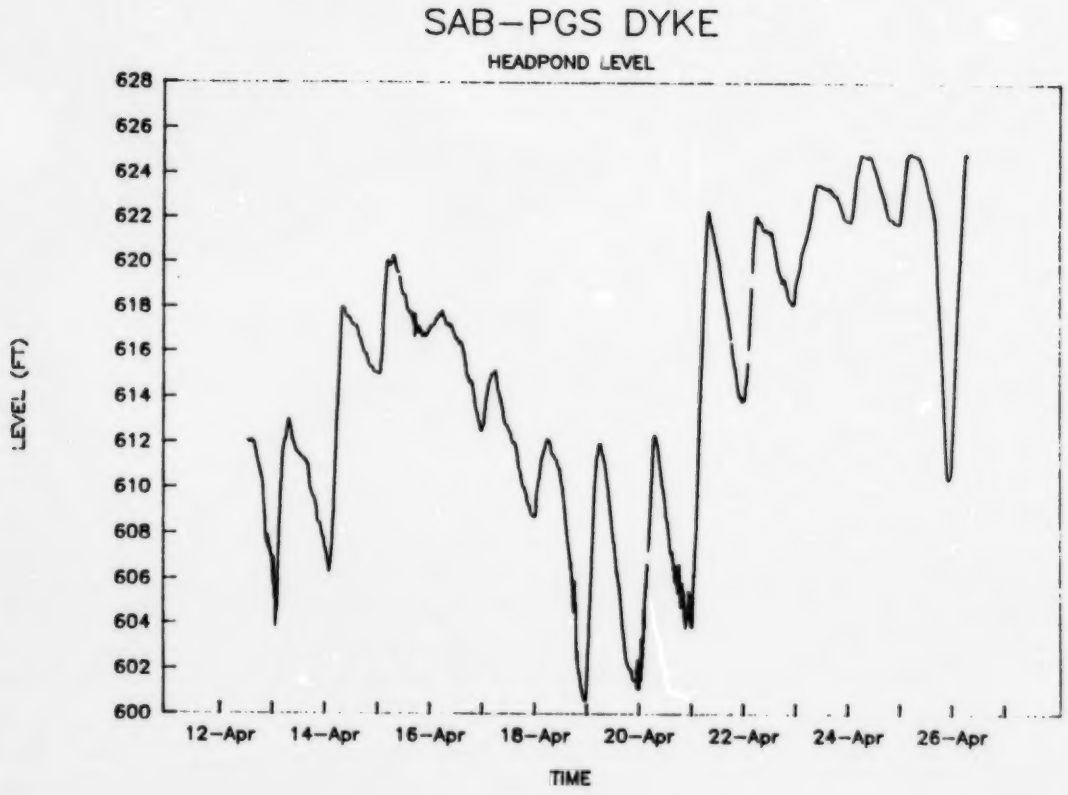


FIGURE 7: Summary of Headpond Level, Air Temperature of Gauge House, and Power Supply - March 28-April 6/91



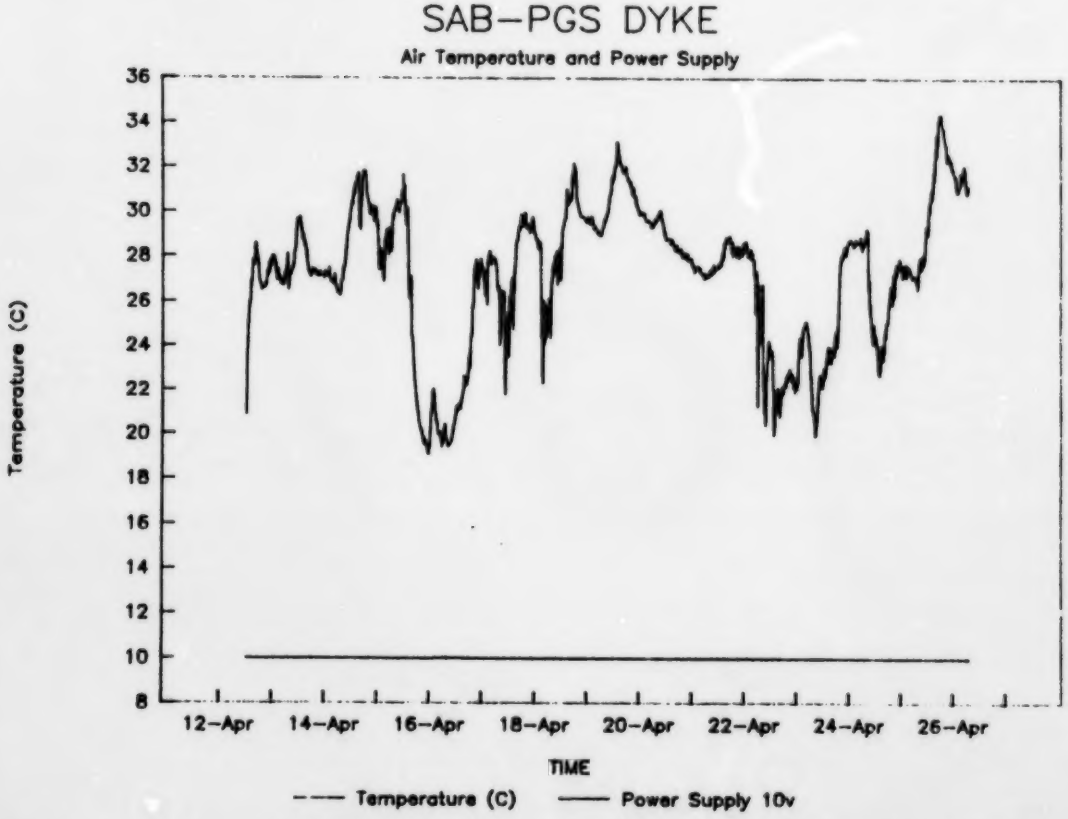
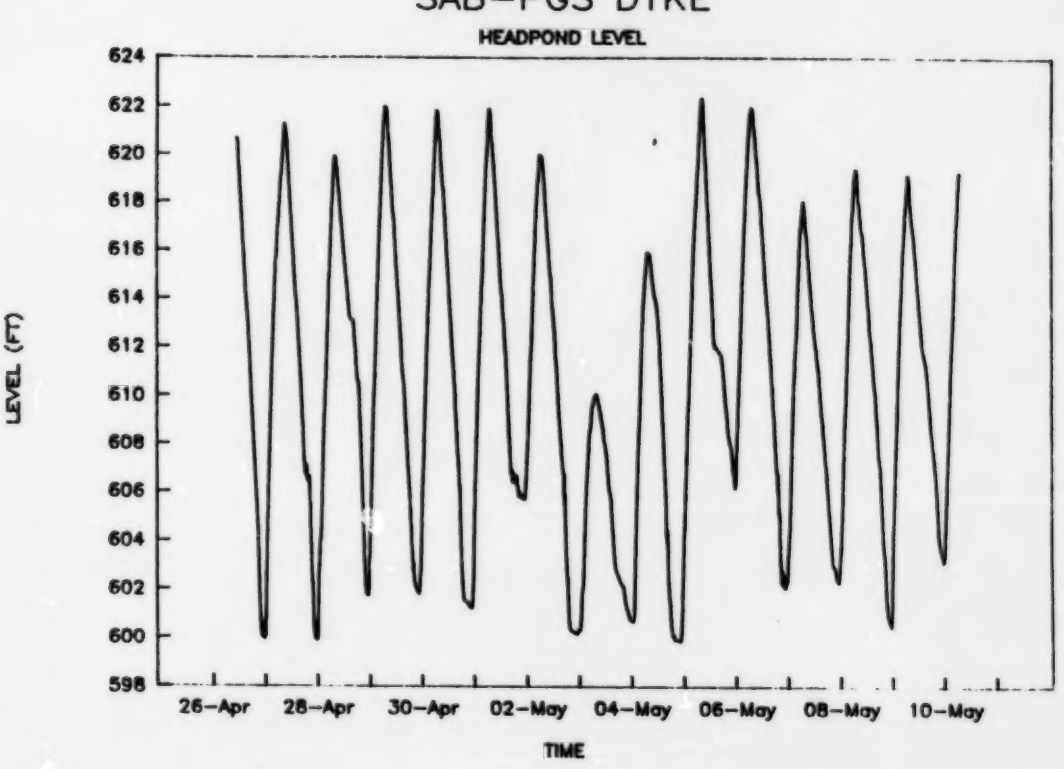


FIGURE 8: Summary of Headpond Level, Air Temperature of Gauge House, and Power Supply - April 12-27/91



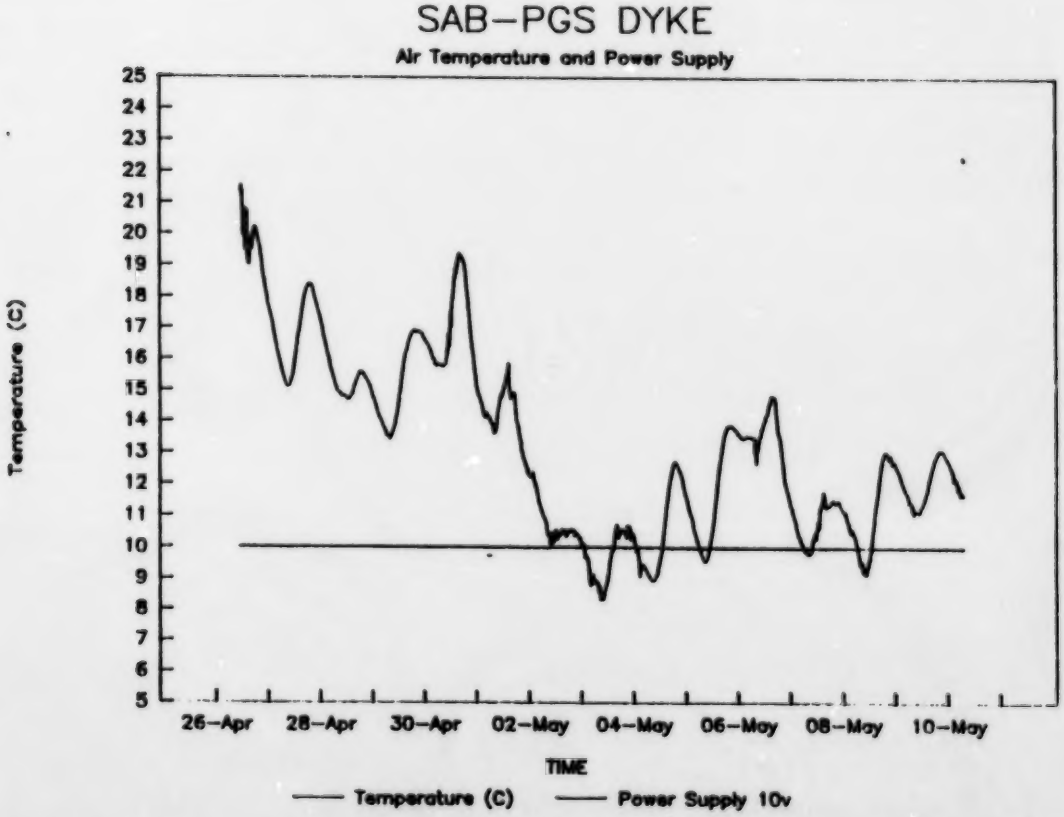
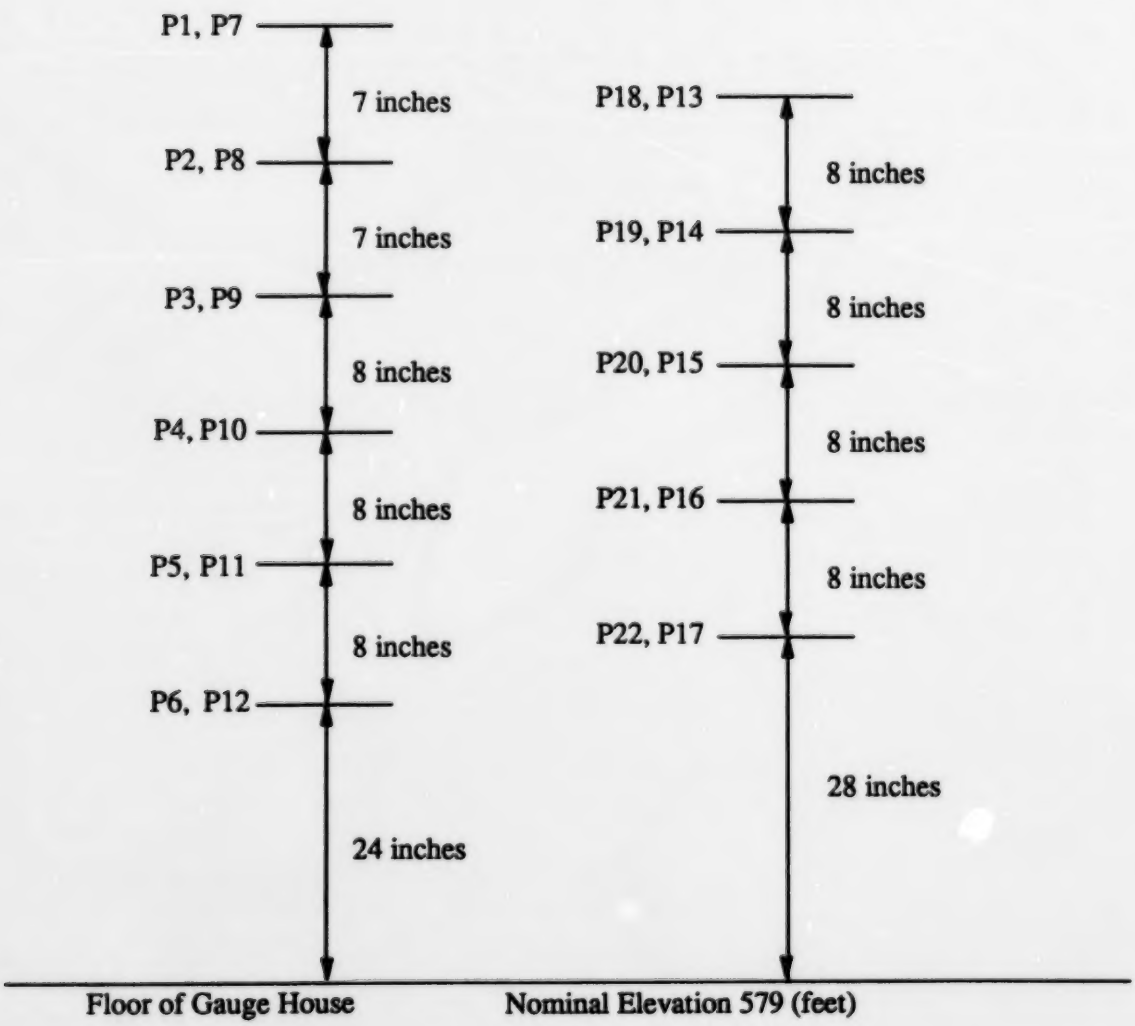


FIGURE 9: Summary of Headpond Level, Air Temperature of Gauge House, and Power Supply - April 27-May 6/91

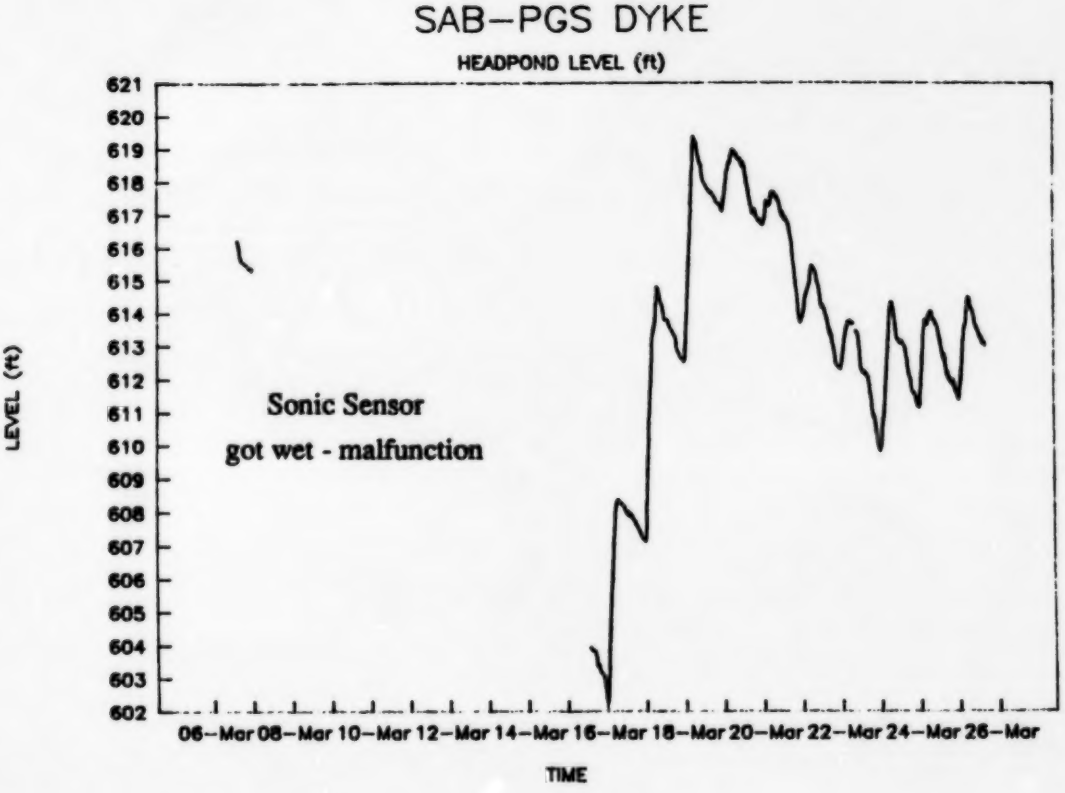
Figure 10 Instrumentation Panel for Pore Water Pressure Gauges And Tranducers

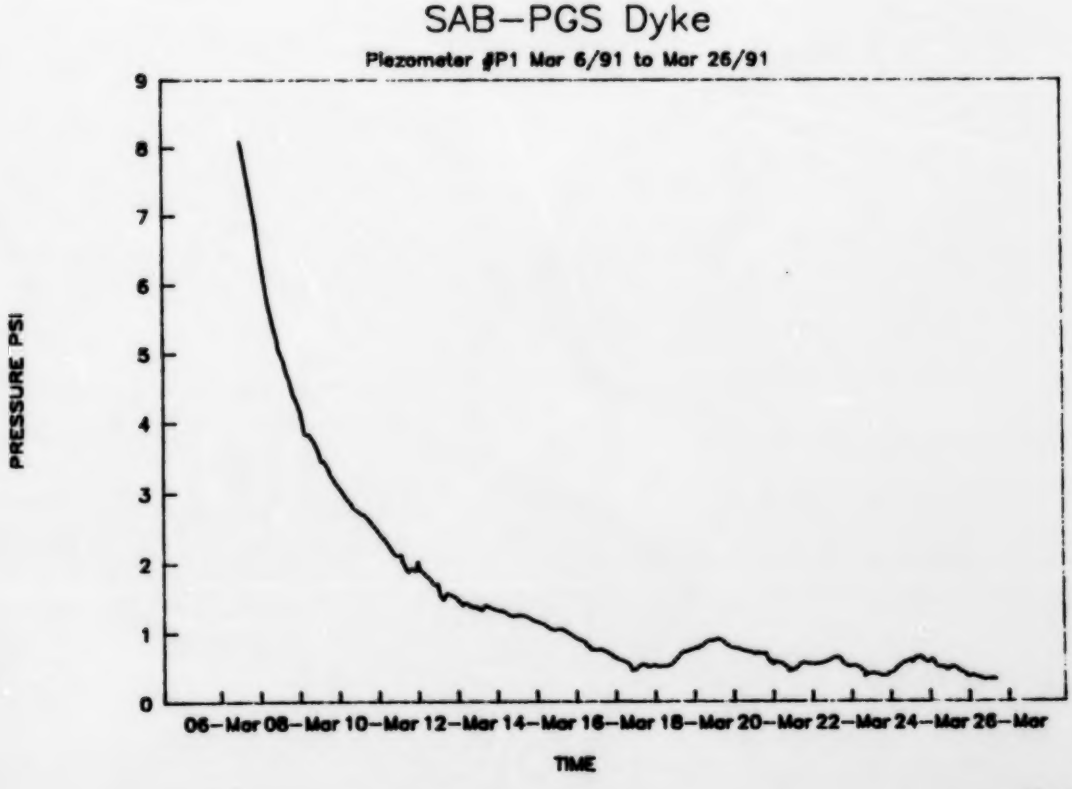


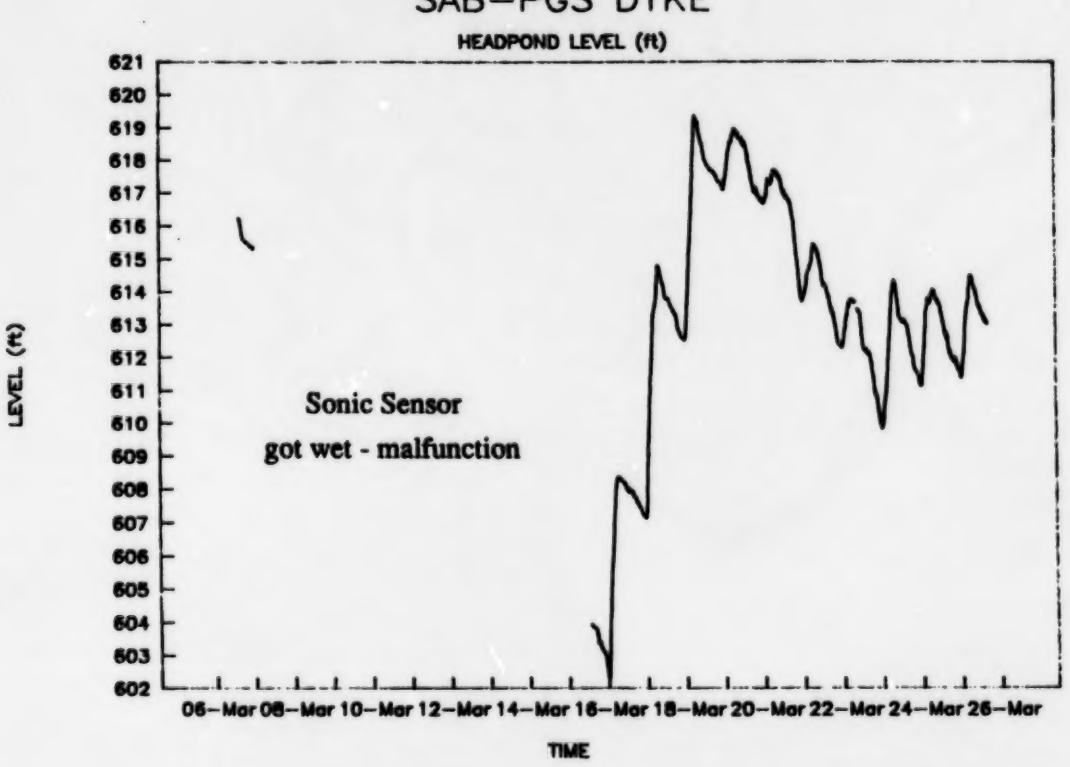
APPENDIX A

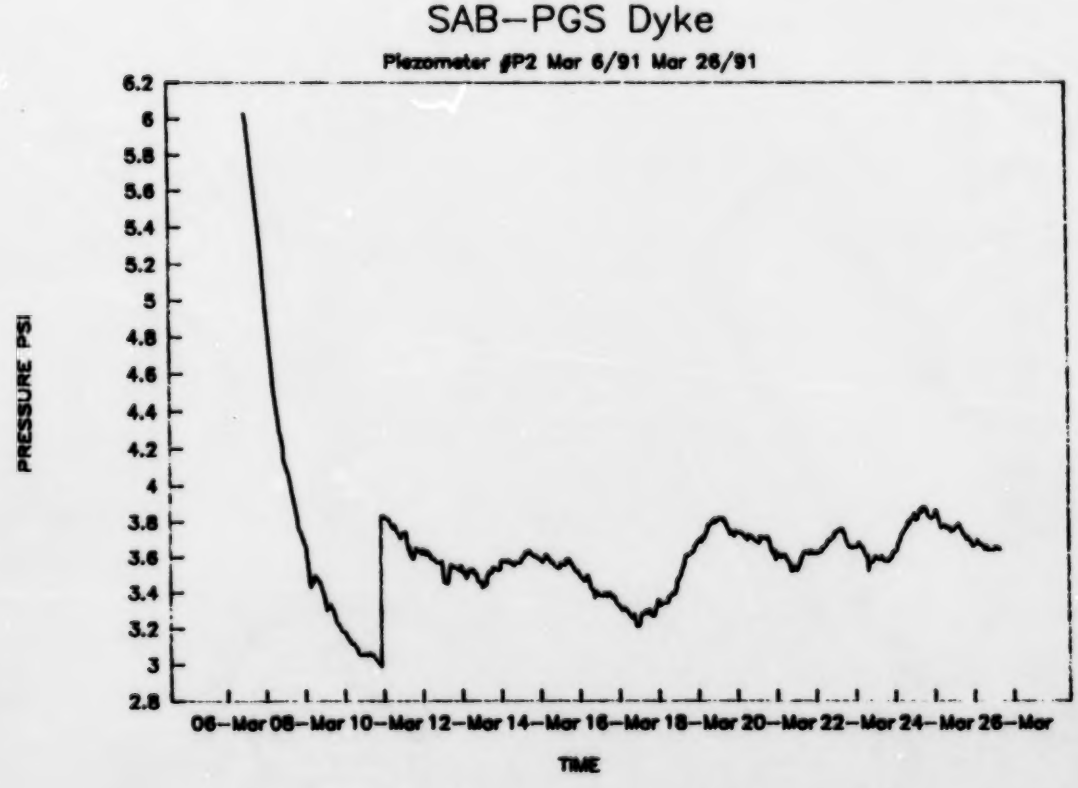
Piezometers #P1 to P6
March 6 to 26, 1991

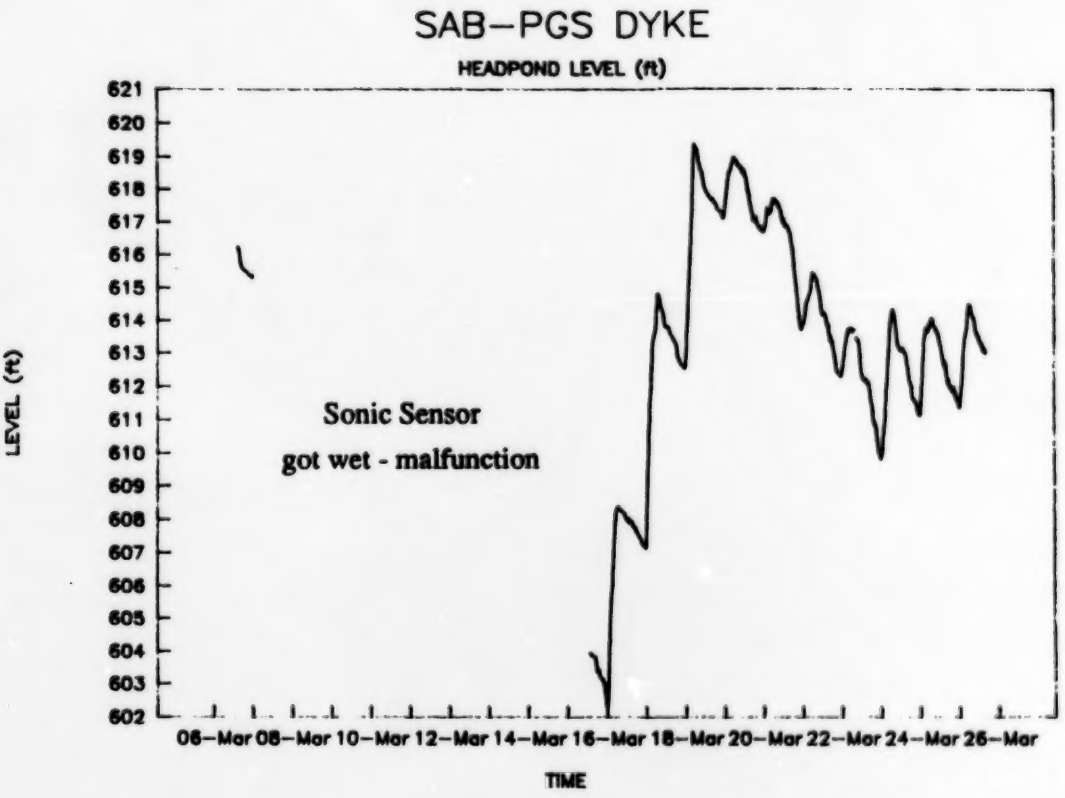
P1 to P6-wk1

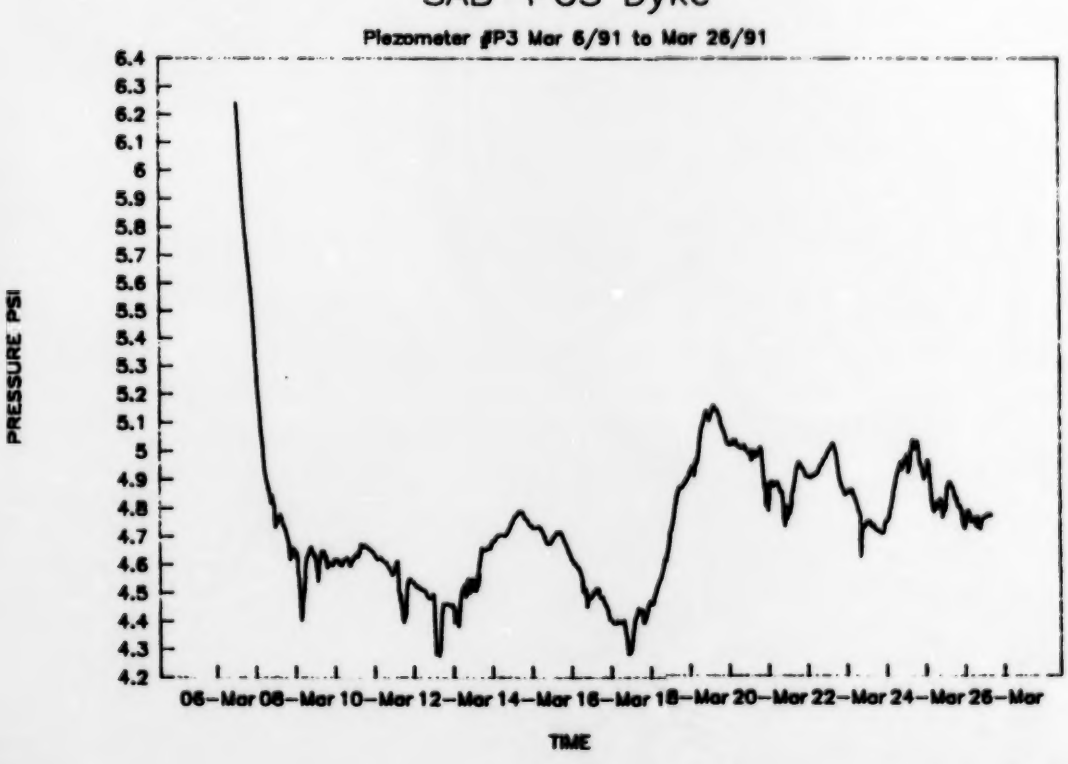

SAB–PGS DYKE
HEADPOND LEVEL (ft)
LEVEL (ft)
621
620
619
618
617
616
615
614
613
612
611
610
609
608
607
606
605
604
603
602
Sonic Sensor
got wet - malfunction
06–Mar 08–Mar 10–Mar 12–Mar 14–Mar 16–Mar 18–Mar 20–Mar 22–Mar 24–Mar 26–Mar
TIME


SAB–PGS Dyke
Piezometer #P1 Mar 6/91 to Mar 26/91
PRESSURE PSI
9
8
7
6
5
4
3
2
1
0
06–Mar 08–Mar 10–Mar 12–Mar 14–Mar 16–Mar 18–Mar 20–Mar 22–Mar 24–Mar 26–Mar
TIME

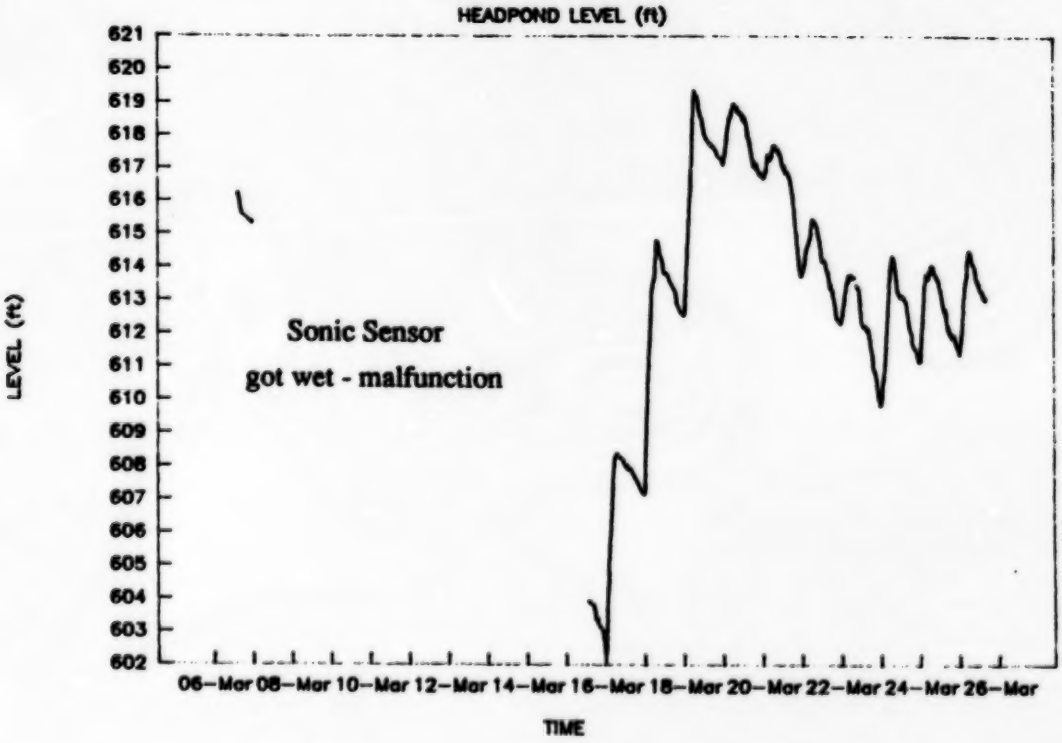

SAB–PGS DYKE
HEADPOND LEVEL (ft)
LEVEL (ft)
621
620
619
618
617
616
615
614
613
612
611
610
609
608
607
606
605
604
603
602
Sonic Sensor
got wet - malfunction
06–Mar 08–Mar 10–Mar 12–Mar 14–Mar 16–Mar 18–Mar 20–Mar 22–Mar 24–Mar 26–Mar
TIME


SAB–PGS Dyke
Piezometer #P2 Mar 6/91 Mar 26/91
PRESSURE PSI
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
06–Mar 08–Mar 10–Mar 12–Mar 14–Mar 16–Mar 18–Mar 20–Mar 22–Mar 24–Mar 26–Mar
TIME

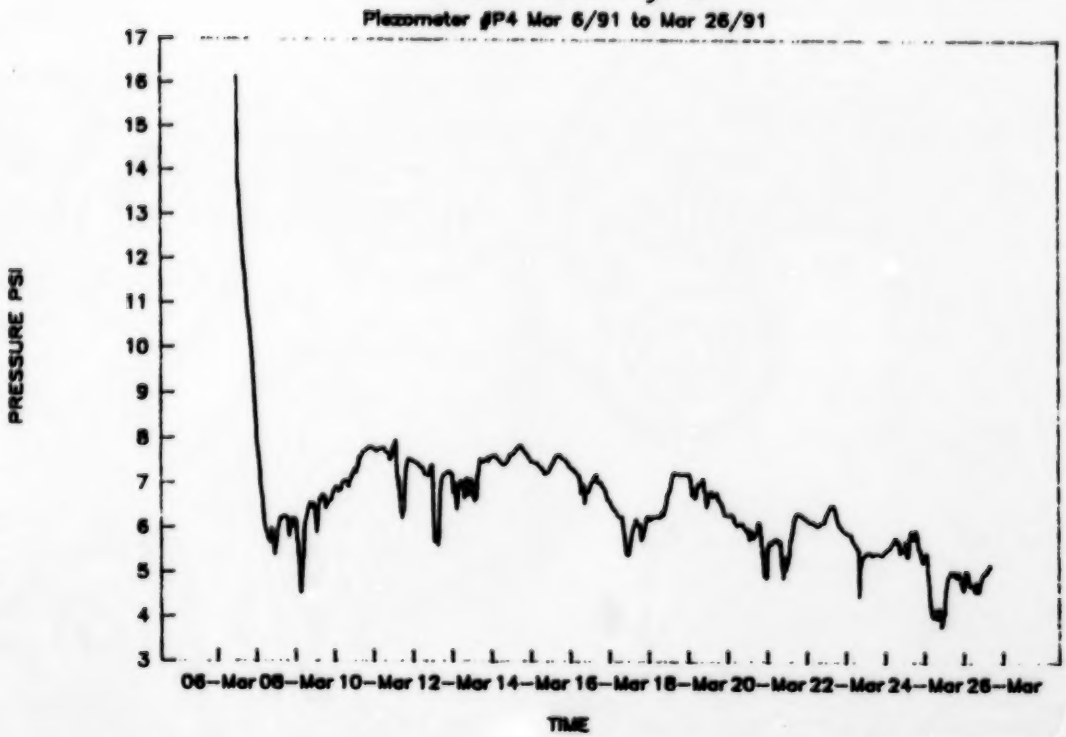

SAB–PGS DYKE
HEADPOND LEVEL (ft)
LEVEL (ft)
621
620
619
618
617
616
615
614
613
612
611
610
609
608
607
606
605
604
603
602
Sonic Sensor
got wet - malfunction
06–Mar 08–Mar 10–Mar 12–Mar 14–Mar 16–Mar 18–Mar 20–Mar 22–Mar 24–Mar 26–Mar
TIME

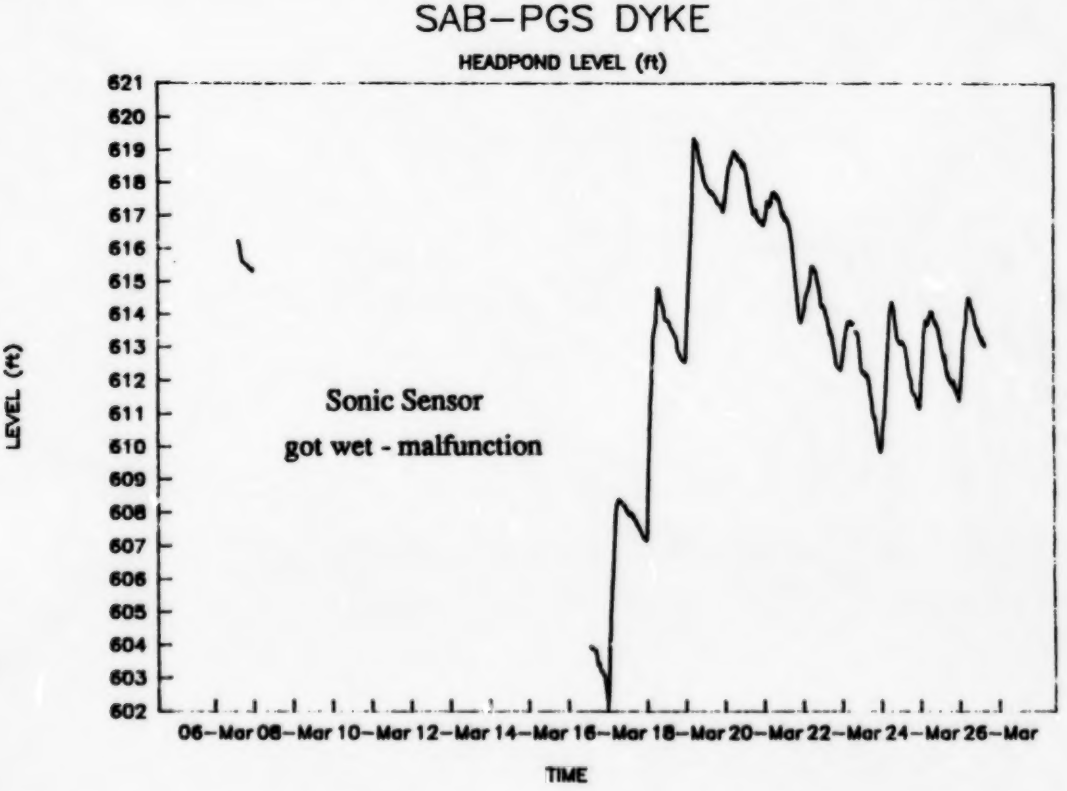

SAB–PGS Dyke
Piezometer #P3 Mar 6/91 to Mar 26/91
PRESSURE PSI
6.4
6.3
6.2
6.1
6
5.9
5.8
5.7
5.6
5.5
5.4
5.3
5.2
5.1
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
06–Mar 08–Mar 10–Mar 12–Mar 14–Mar 16–Mar 18–Mar 20–Mar 22–Mar 24–Mar 26–Mar
TIME

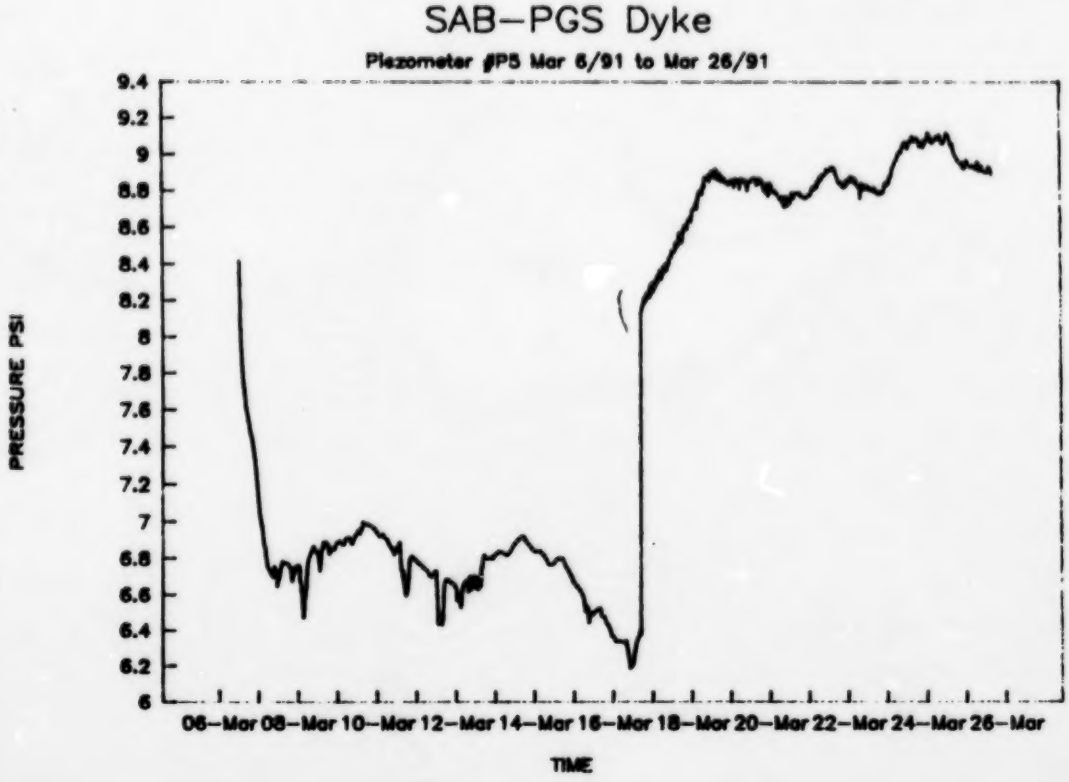
SAB–PGS DYKE



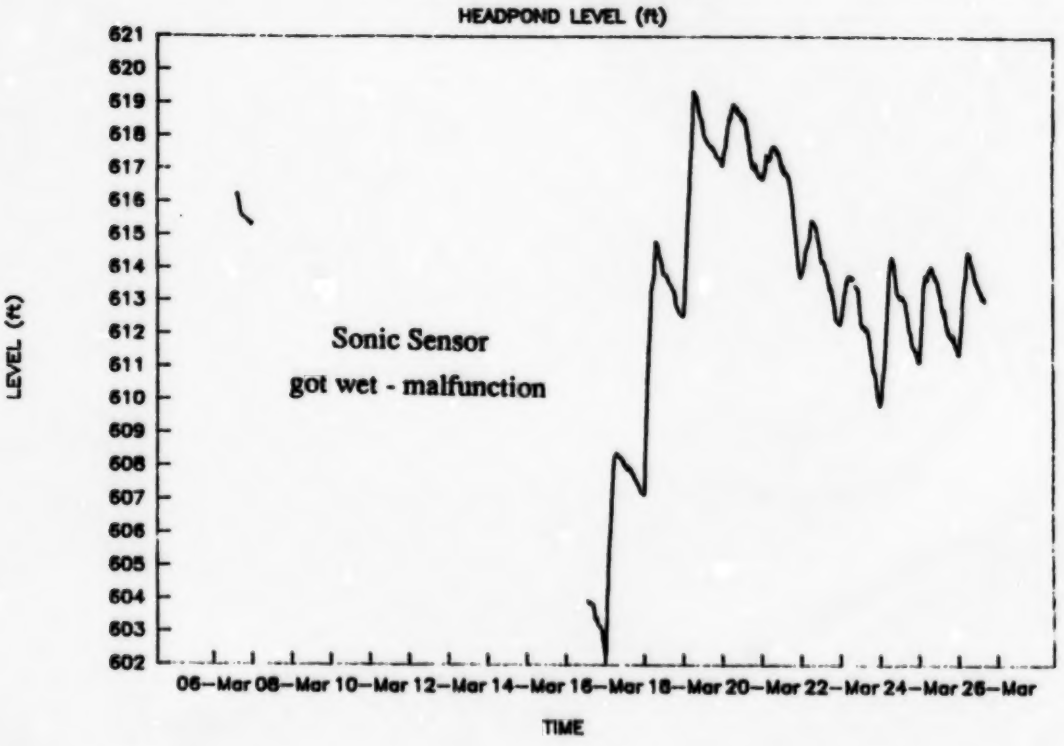
SAB–PGS Dyke



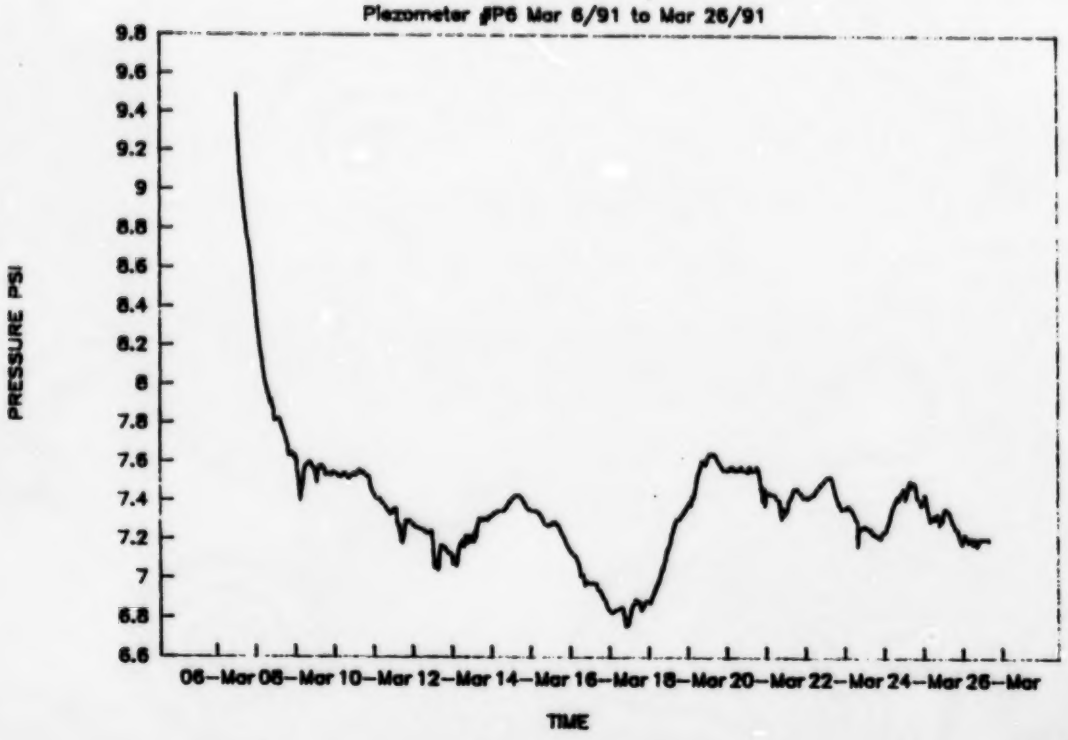

SAB–PGS DYKE
HEADPOND LEVEL (ft)
LEVEL (ft)
621
620
619
618
617
616
615
614
613
612
611
610
609
608
607
606
605
604
603
602
Sonic Sensor
got wet - malfunction
06–Mar 08–Mar 10–Mar 12–Mar 14–Mar 16–Mar 18–Mar 20–Mar 22–Mar 24–Mar 26–Mar
TIME


SAB–PGS Dyke
Piezometer #P5 Mar 6/91 to Mar 26/91
PRESSURE PSI
9.4
9.2
9
8.8
8.6
8.4
8.2
8
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
06–Mar 08–Mar 10–Mar 12–Mar 14–Mar 16–Mar 18–Mar 20–Mar 22–Mar 24–Mar 26–Mar
TIME

SAB–PGS DYKE



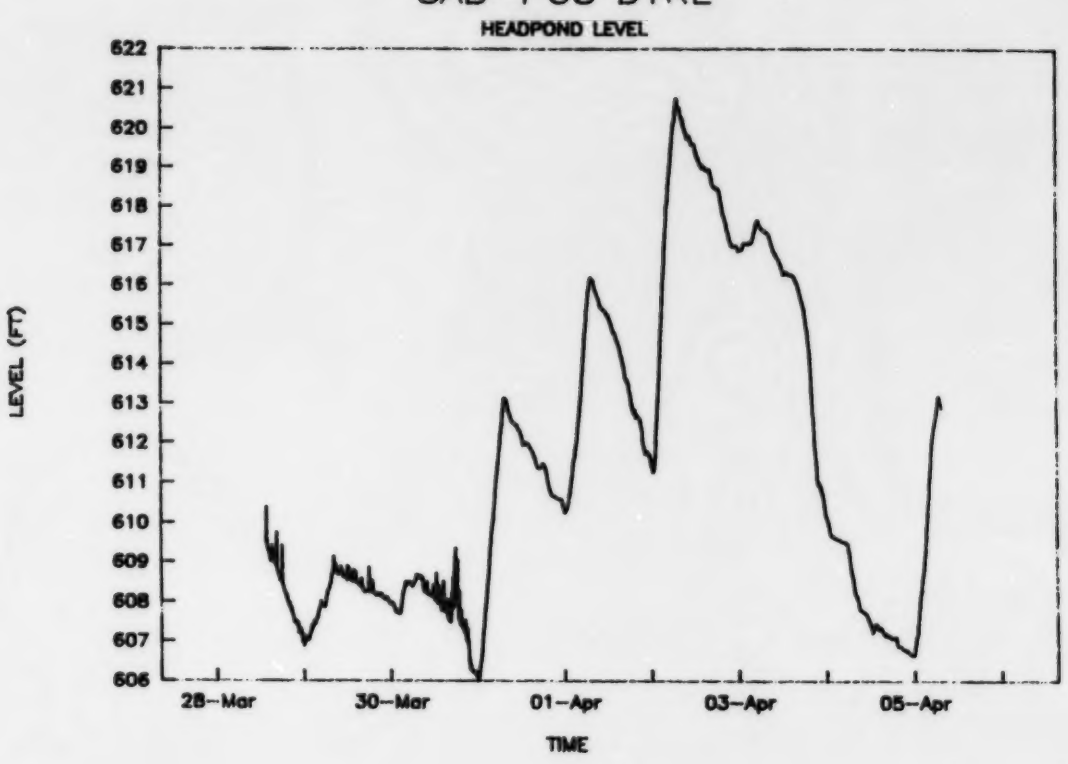
SAB--PGS Dyke

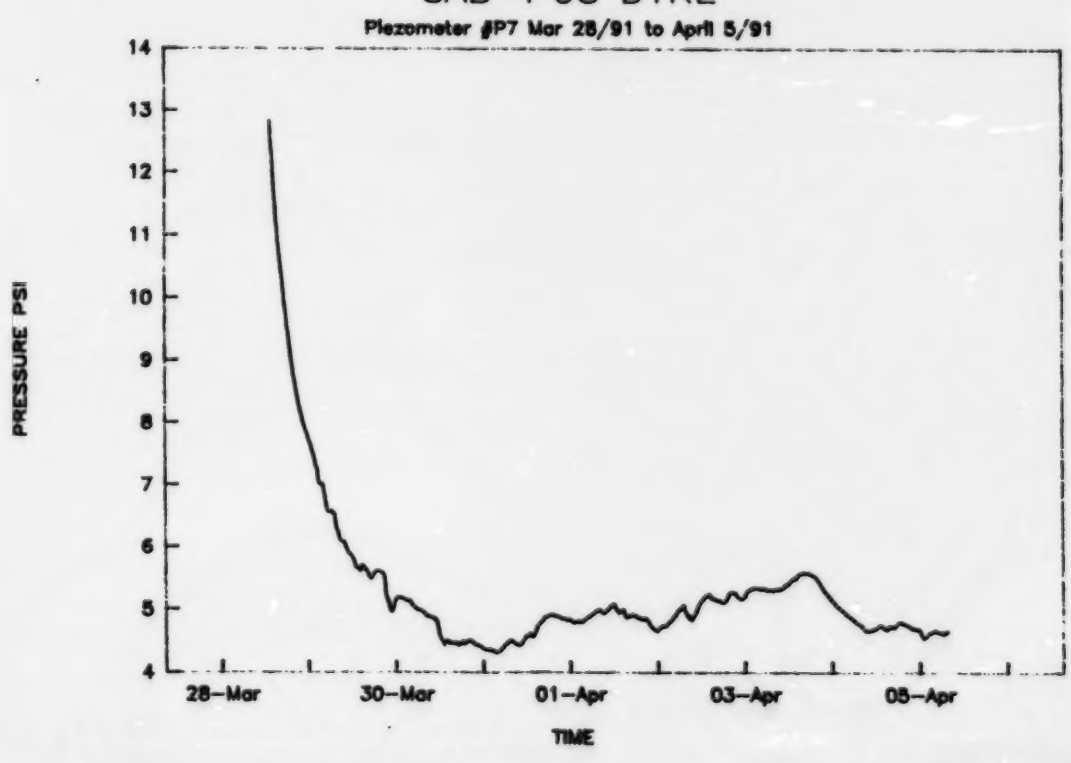


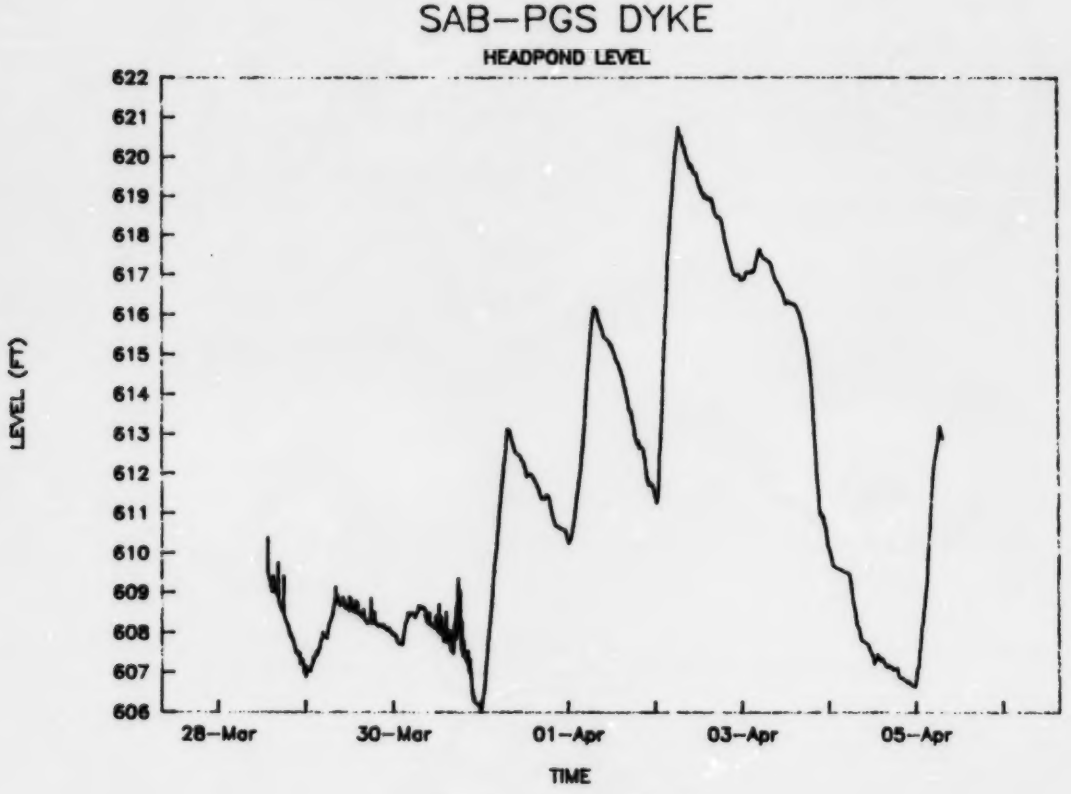
APPENDIX B

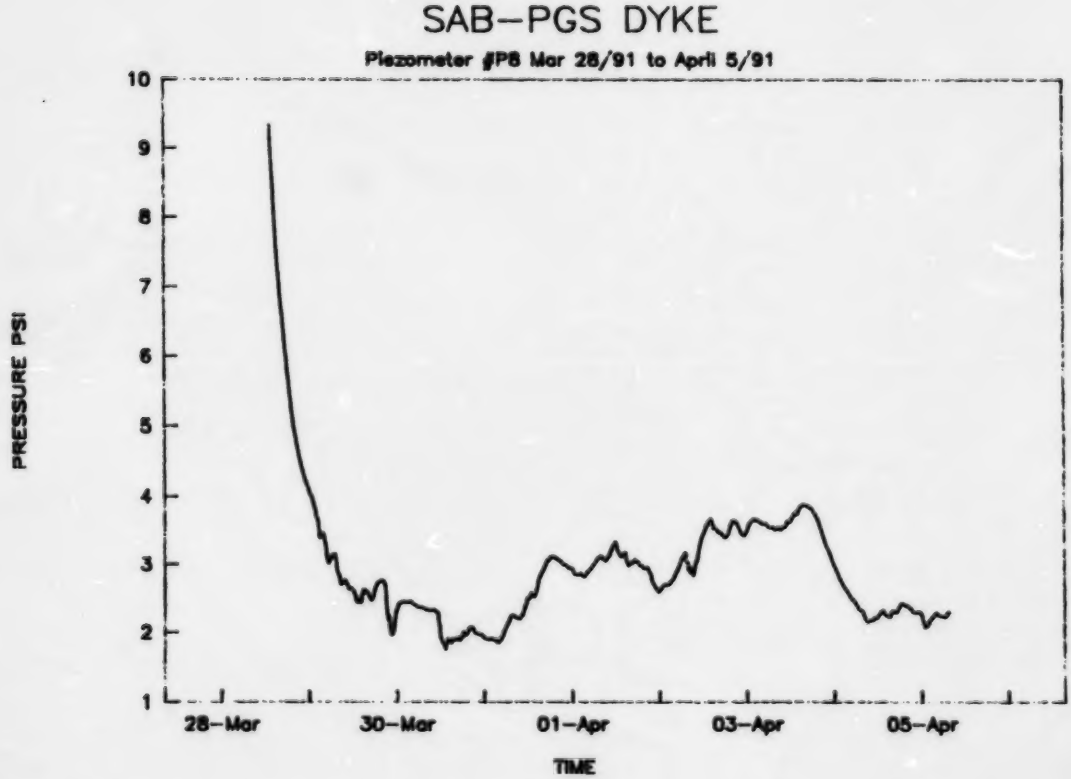
Piezometers #P2 to P12
March 28 to April 6, 1991

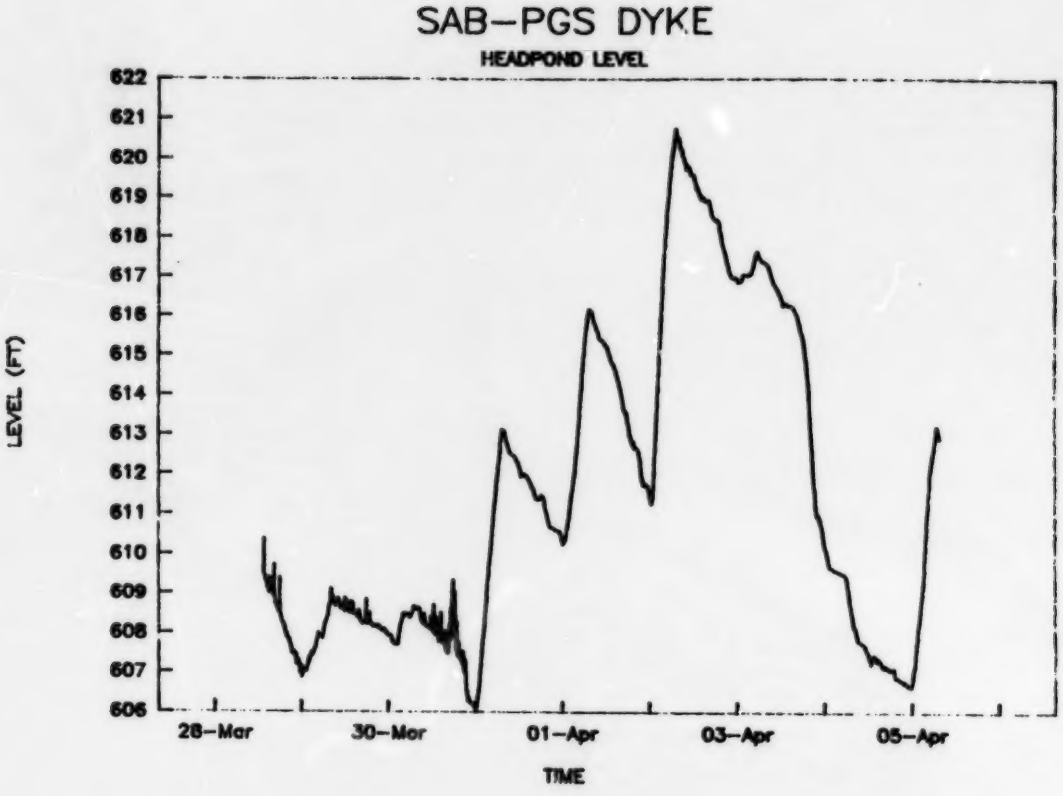
P7 to P12.wk1

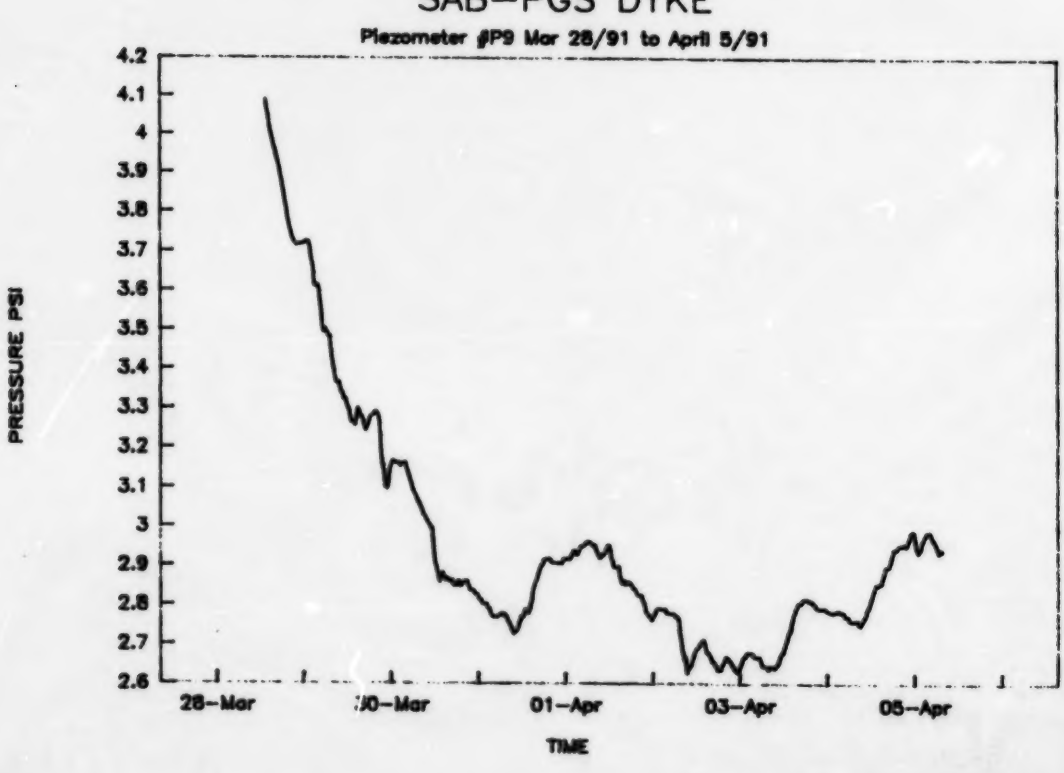

SAB–PGS DYKE
HEADPOND LEVEL
LEVEL (FT)
622
621
620
619
618
617
616
615
614
613
612
611
610
609
608
607
606
28–Mar
30–Mar
01–Apr
03–Apr
05–Apr
TIME


SAB–PGS DYKE
Piezometer #P7 Mar 28/91 to April 5/91
PRESSURE PSI
14
13
12
11
10
9
8
7
6
5
4
28–Mar
30–Mar
01–Apr
03–Apr
05–Apr
TIME


SAB–PGS DYKE
HEADPOND LEVEL
LEVEL (FT)
622
621
620
619
618
617
616
615
614
613
612
611
610
609
608
607
606
28–Mar
30–Mar
01–Apr
03–Apr
05–Apr
TIME

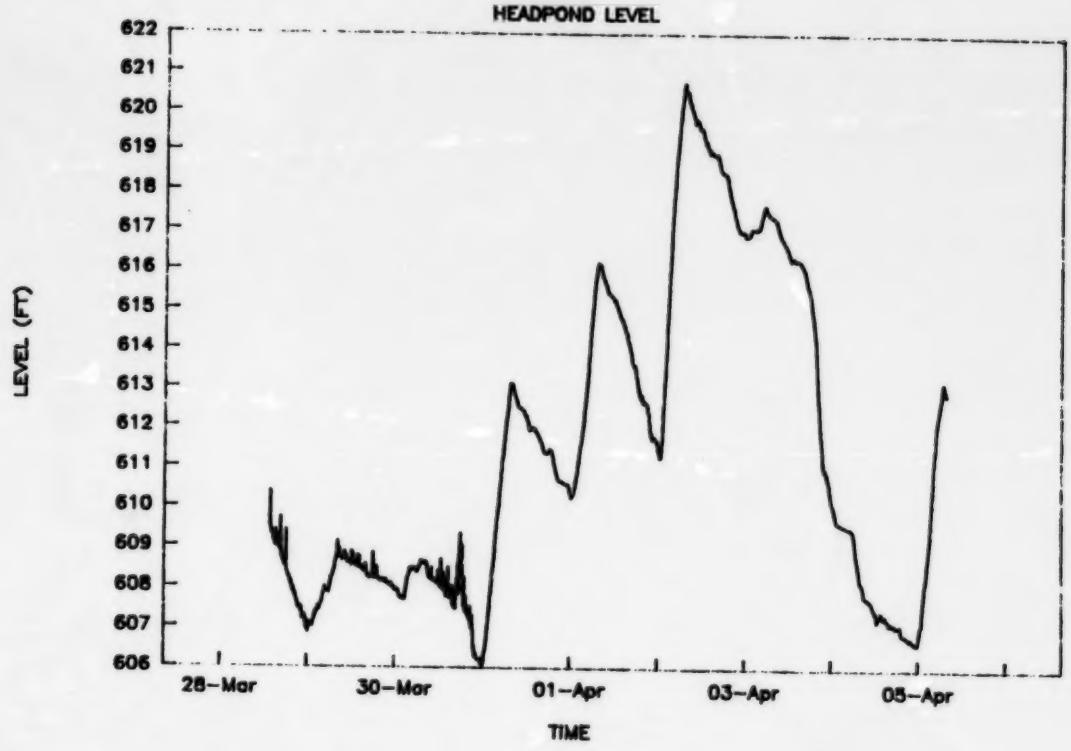

SAB–PGS DYKE
Piezometer #P8 Mar 28/91 to April 5/91
PRESSURE PSI
10
9
8
7
6
5
4
3
2
1
28–Mar
30–Mar
01–Apr
03–Apr
05–Apr
TIME


SAB–PGS DYKE
HEADPOND LEVEL
LEVEL (FT)
622
621
620
619
618
617
616
615
614
613
612
611
610
609
608
607
606
28–Mar
30–Mar
01–Apr
03–Apr
05–Apr
TIME


SAB–PGS DYKE
Piezometer #P9 Mar 28/91 to April 5/91
PRESSURE PSI
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
2.7
2.6
28–Mar
30–Mar
01–Apr
03–Apr
05–Apr
TIME

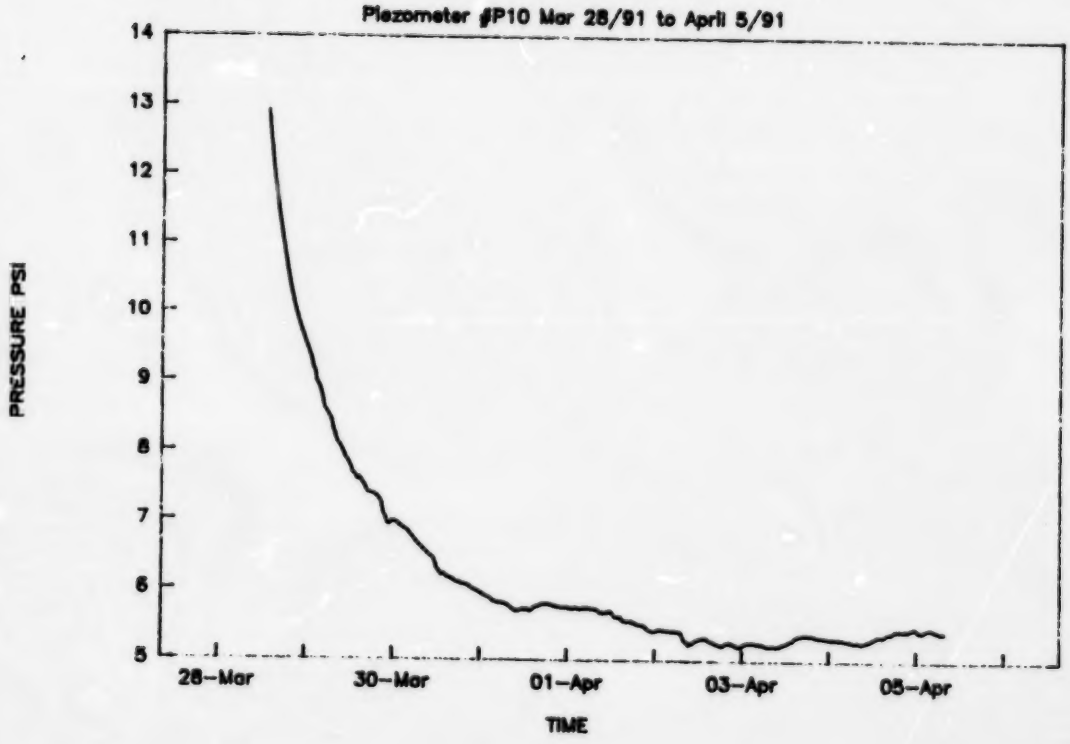
SAB–PGS DYKE

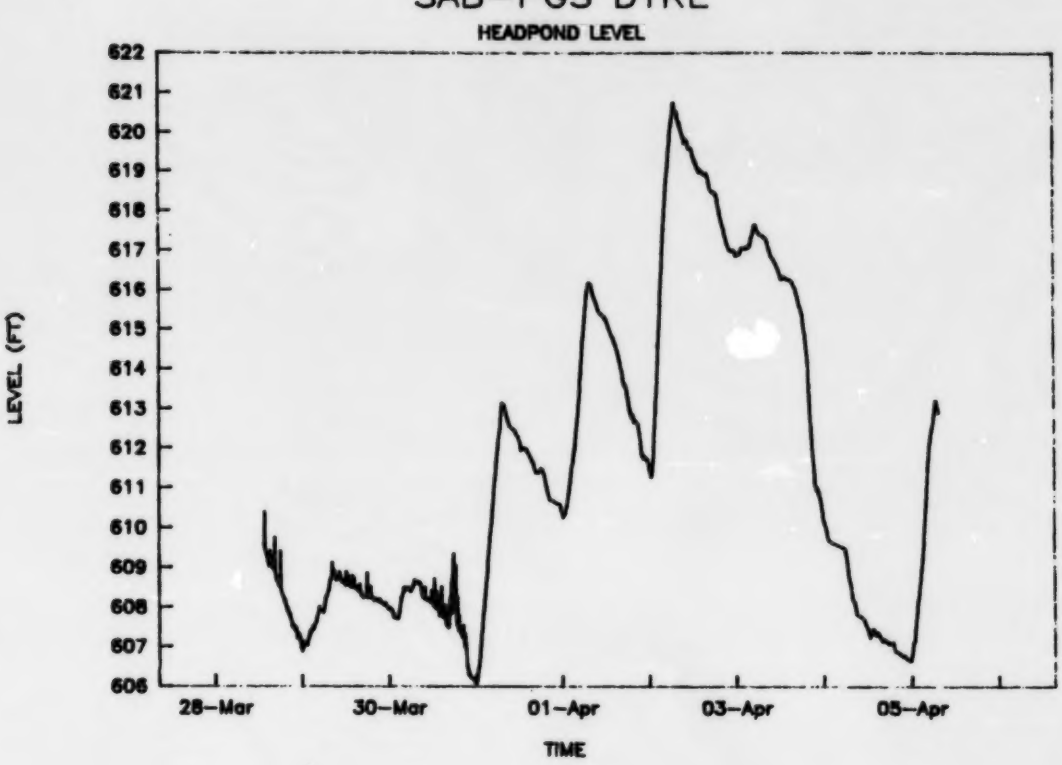
HEADPOND LEVEL

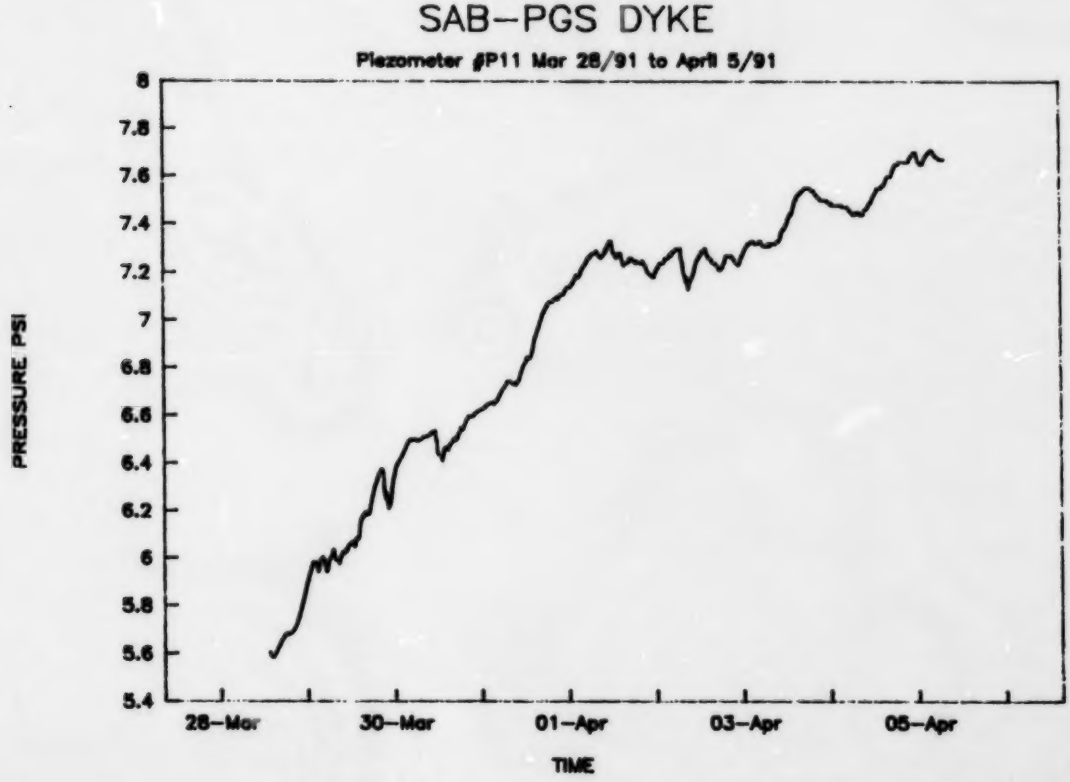


SAB–PGS DYKE

Piezometer #P10 Mar 28/91 to April 5/91

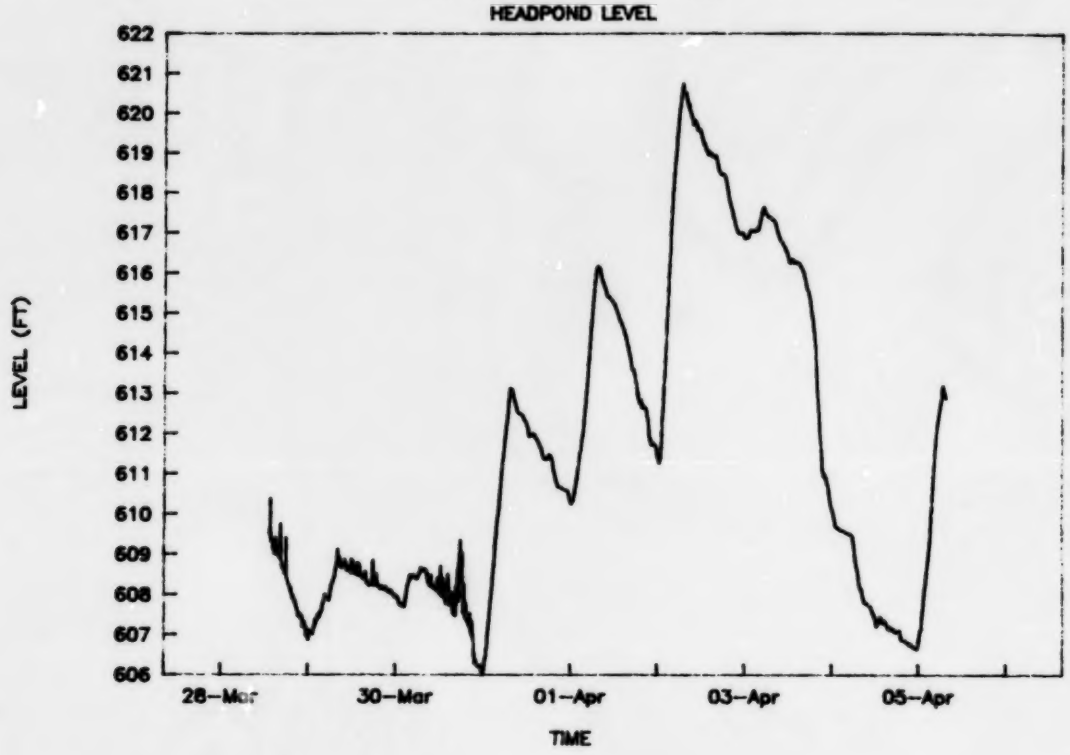



SAB–PGS DYKE
HEADPOND LEVEL
LEVEL (FT)
622
621
620
619
618
617
616
615
614
613
612
611
610
609
608
607
606
28–Mar
30–Mar
01–Apr
03–Apr
05–Apr
TIME


SAB–PGS DYKE
Piezometer #P11 Mar 28/91 to April 5/91
PRESSURE PSI
8
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
28–Mar
30–Mar
01–Apr
03–Apr
05–Apr
TIME

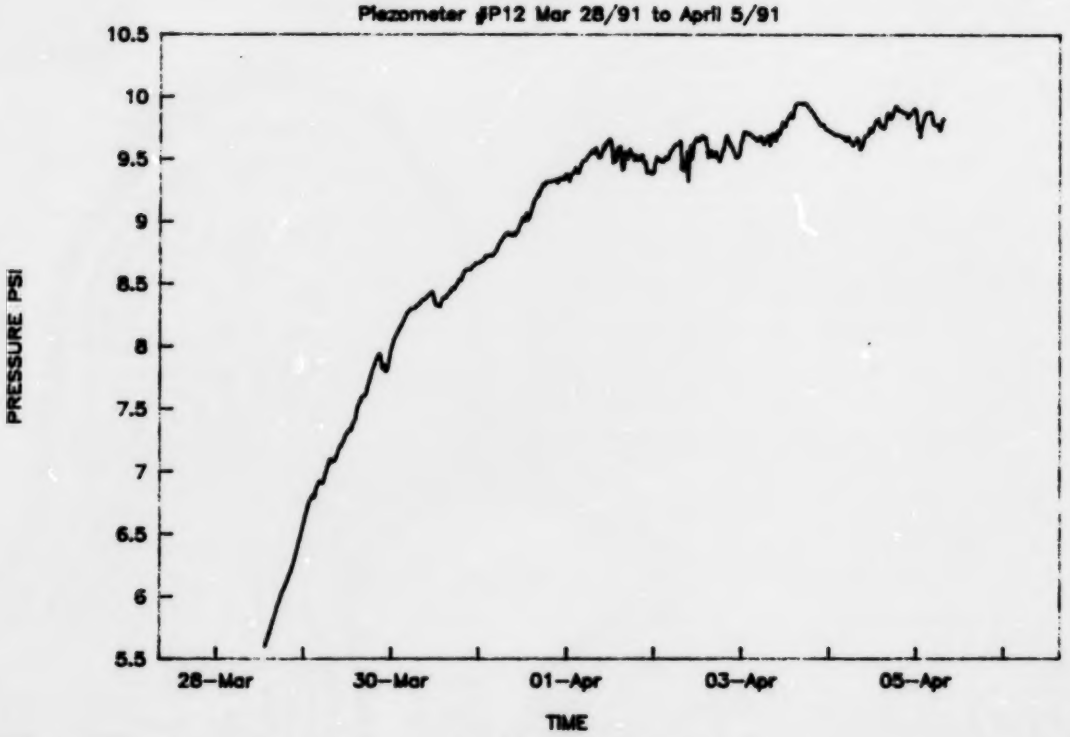
SAB–PGS DYKE

HEADPOND LEVEL



SAB–PGS DYKE

Piezometer #P12 Mar 28/91 to April 5/91



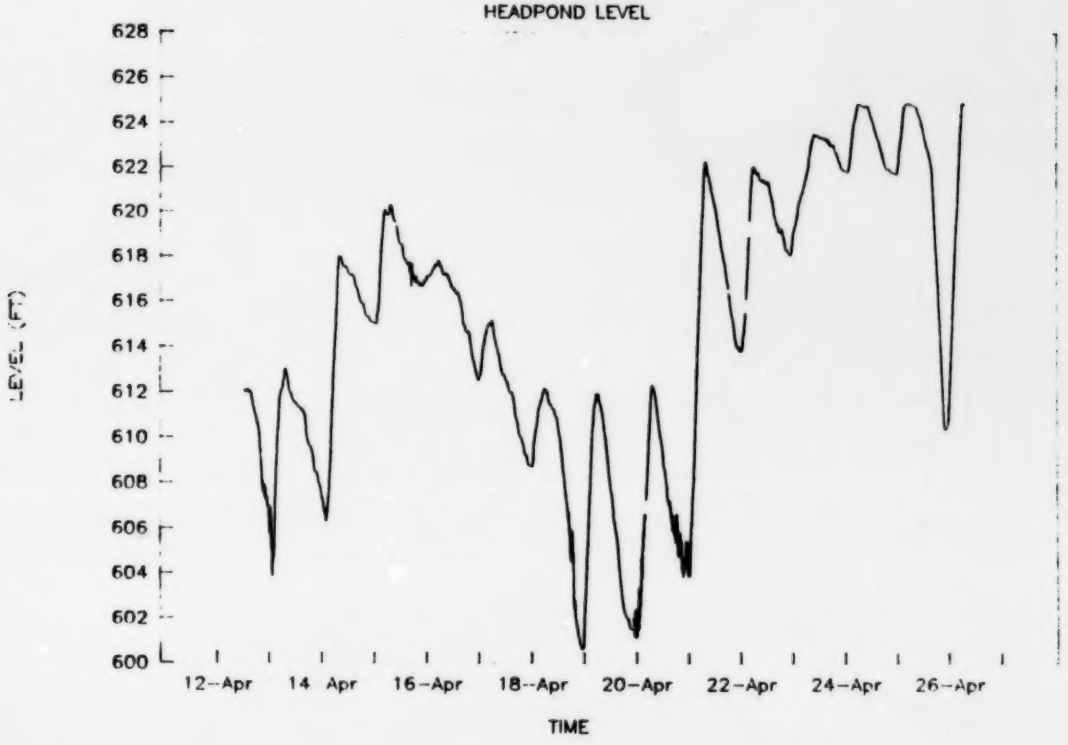
APPENDIX C

Piezometers #P13 to P18
April 12 to April 26, 1991

P13 to P18.wk1

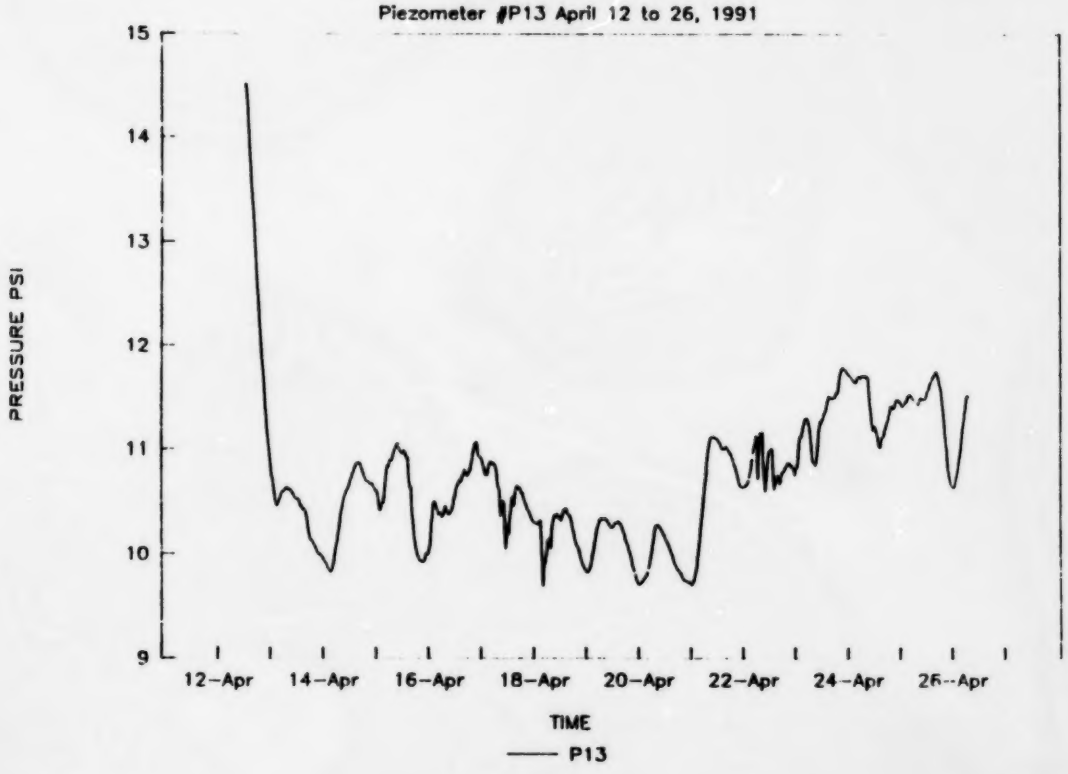
SAB–PGS DYKE

HEADPOND LEVEL



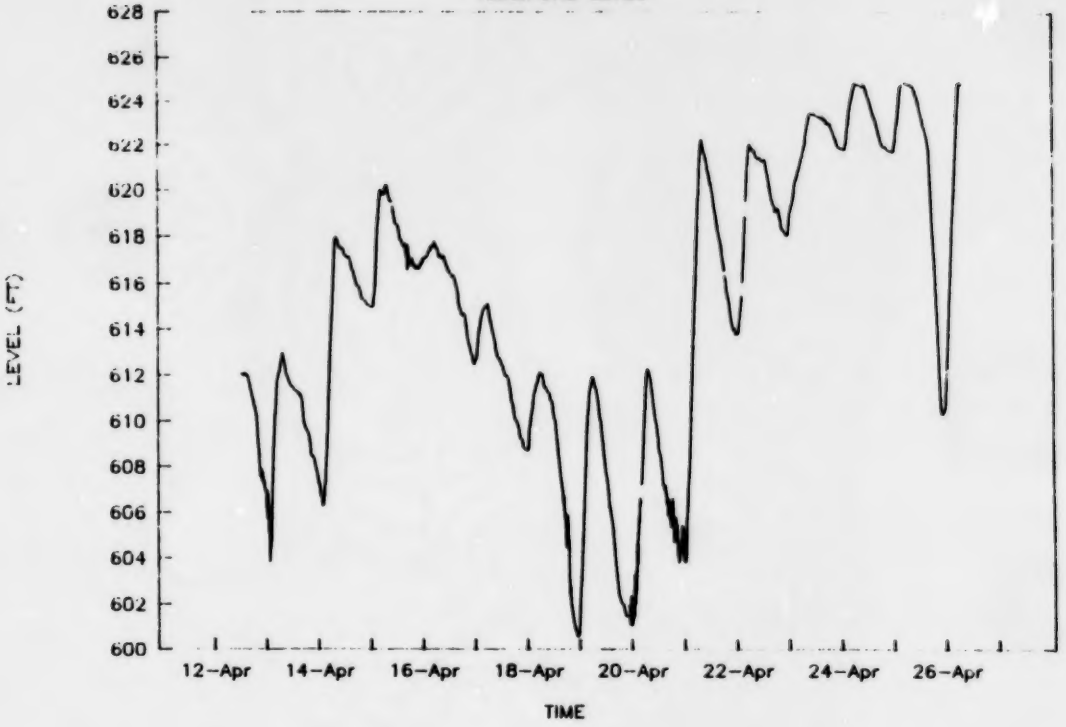
SAB–PGS DYKE

Piezometer #P13 April 12 to 26, 1991



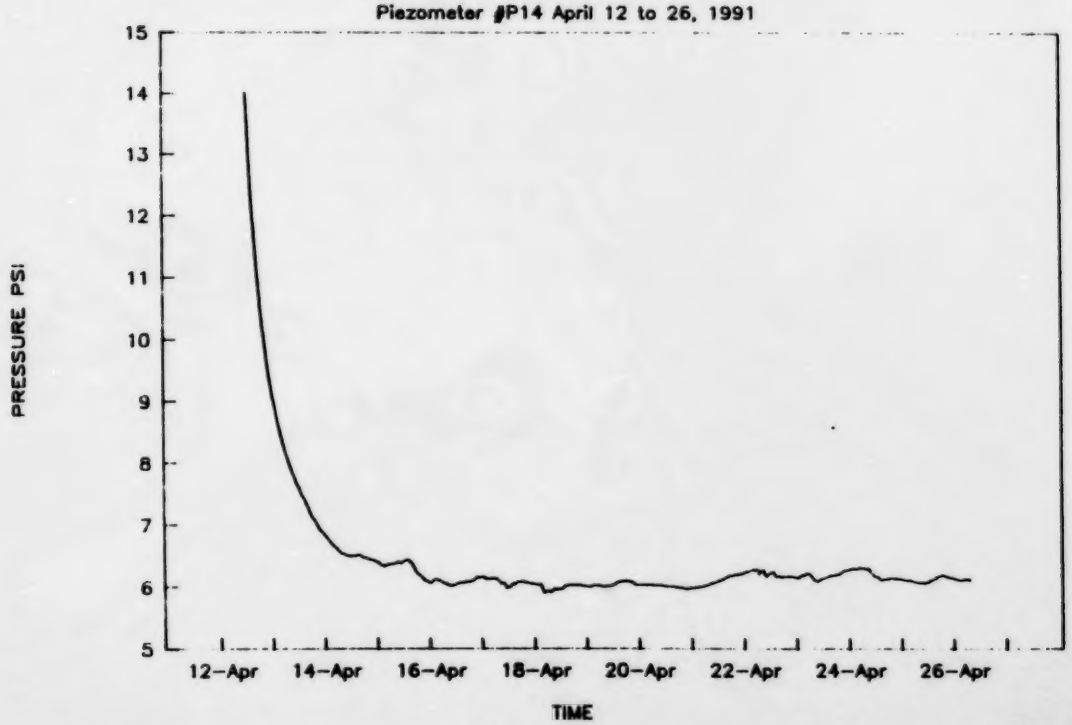
SAB–PGS DYKE

HEADPOND LEVEL

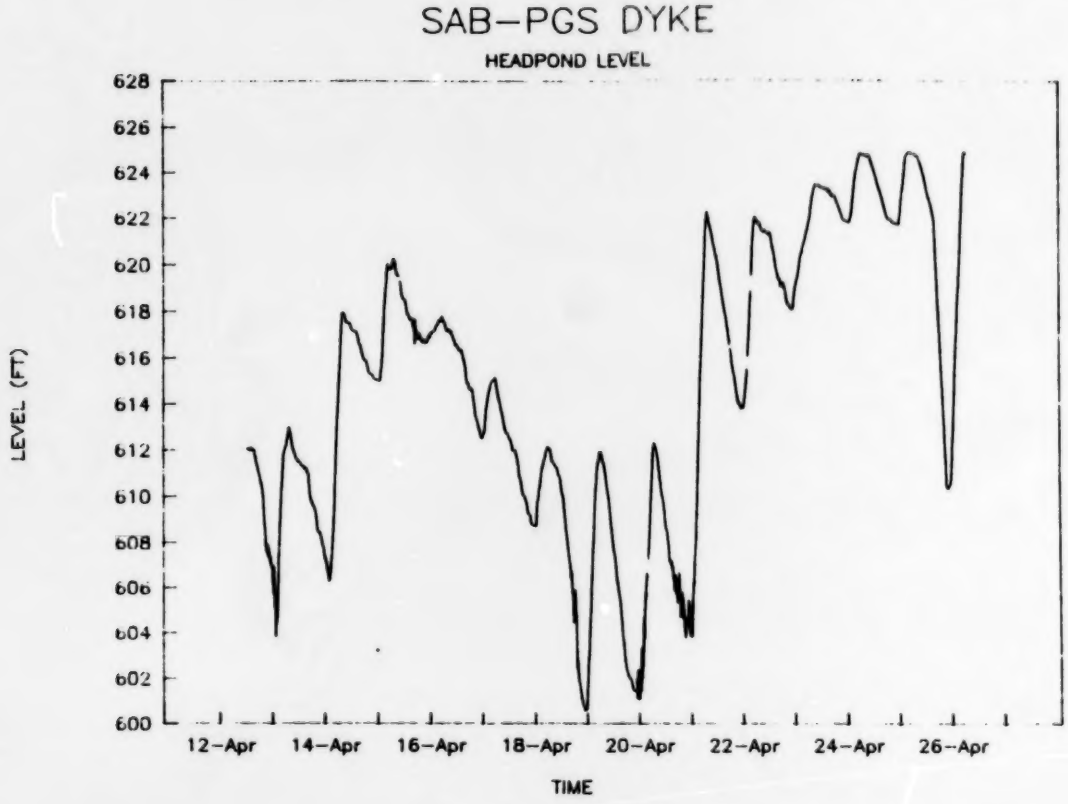


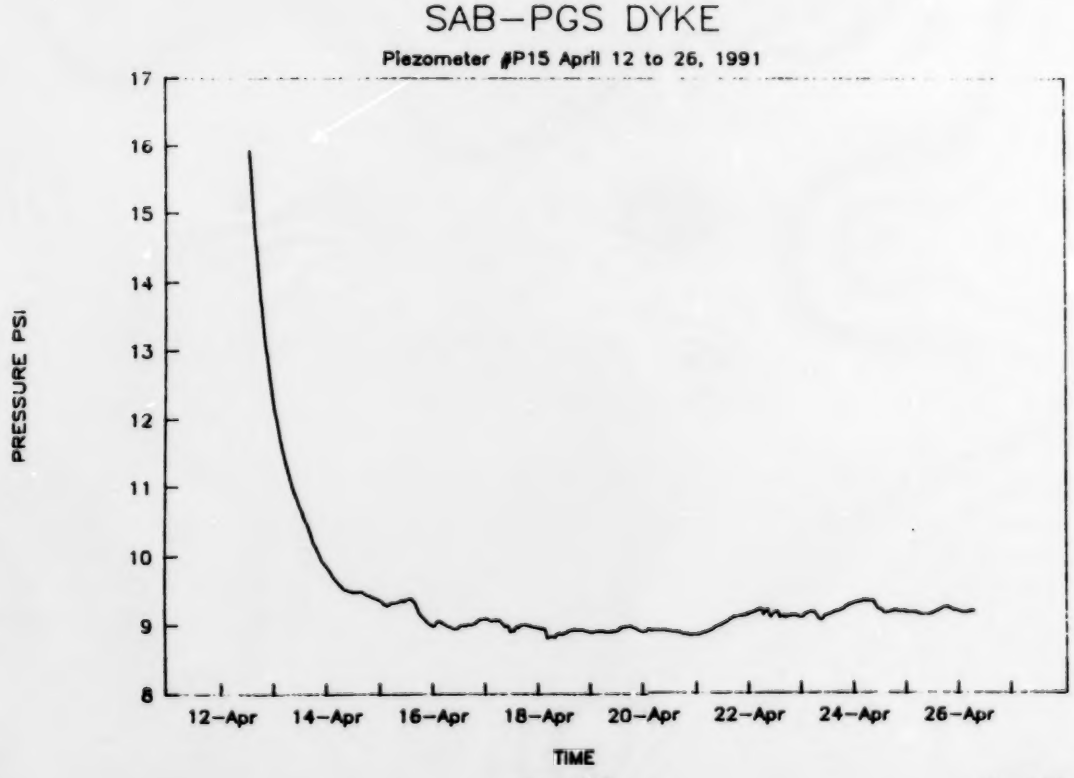
SAB–PGS DYKE

Piezometer #P14 April 12 to 26, 1991



91-133

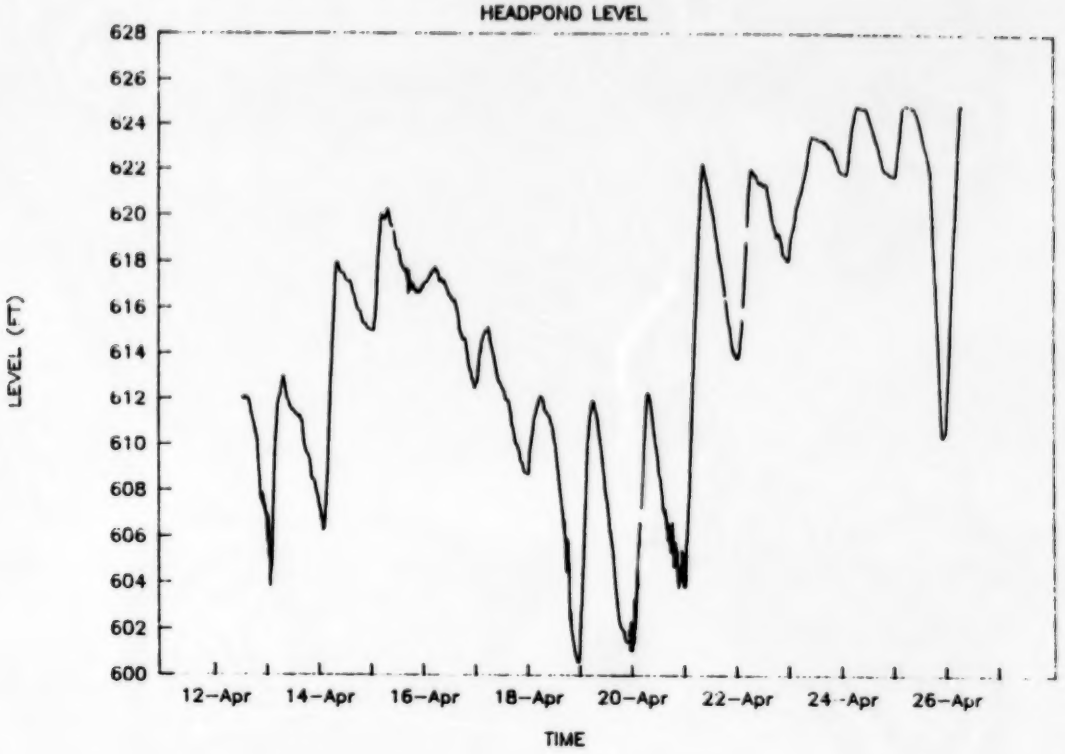

SAB–PGS DYKE
HEADPOND LEVEL
LEVEL (FT)
628
626
624
622
620
618
616
614
612
610
608
606
604
602
600
12–Apr
14–Apr
16–Apr
18–Apr
20–Apr
22–Apr
24–Apr
26–Apr
TIME


SAB–PGS DYKE
Piezometer #P15 April 12 to 26, 1991
PRESSURE PSI
17
16
15
14
13
12
11
10
9
8
12–Apr
14–Apr
16–Apr
18–Apr
20–Apr
22–Apr
24–Apr
26–Apr
TIME
P15

91-133.

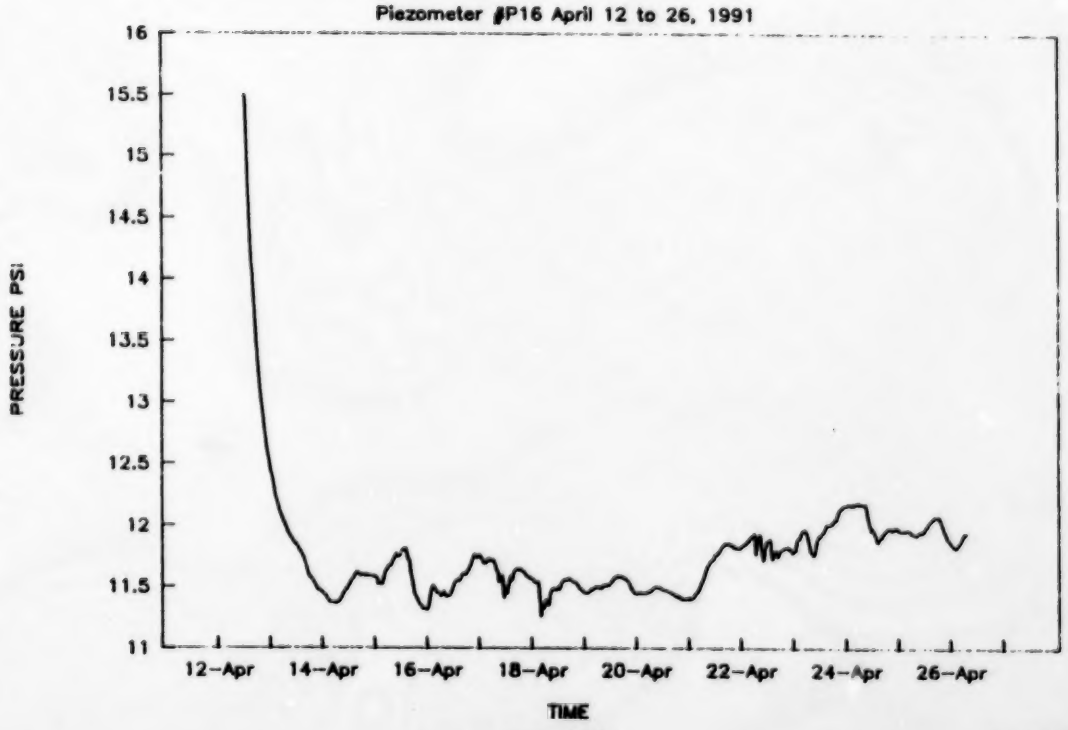
SAB–PGS DYKE

HEADPOND LEVEL

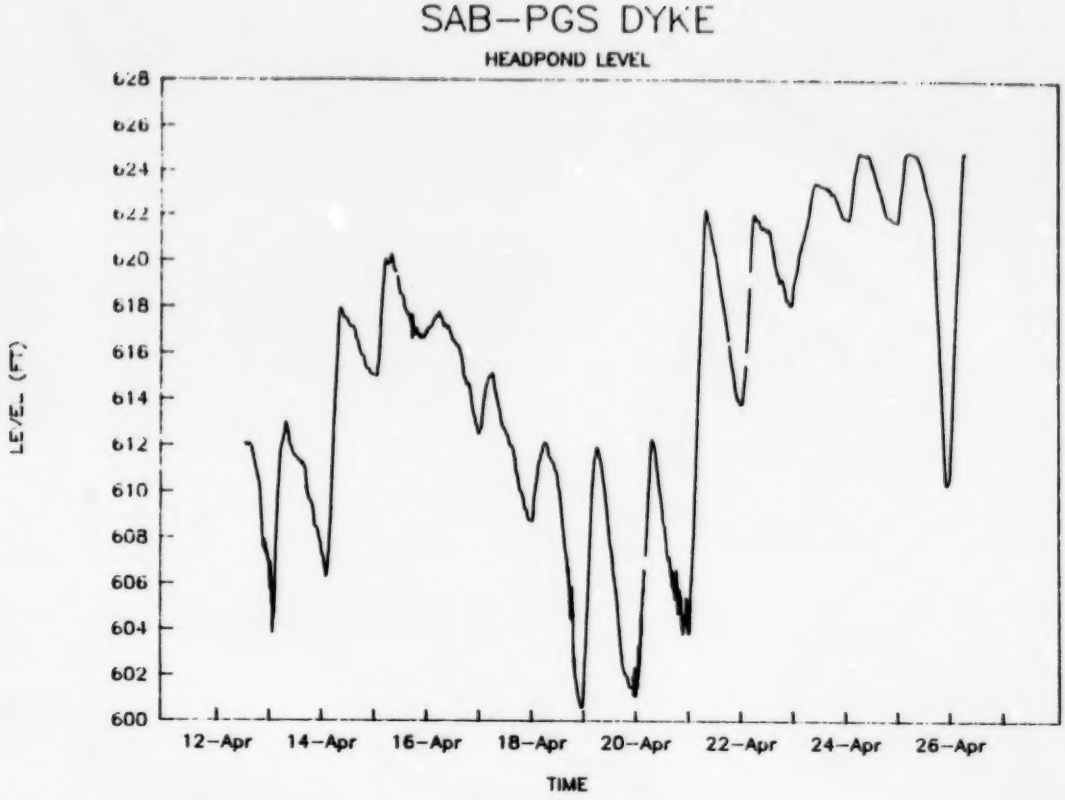


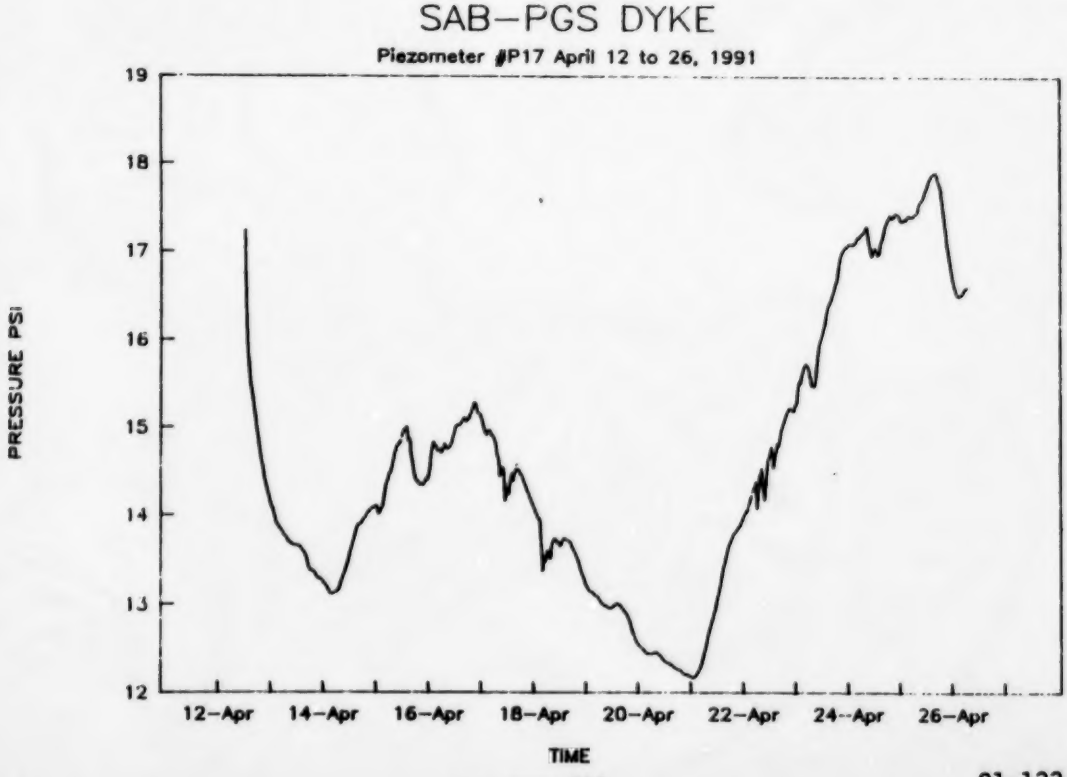
SAB–PGS DYKE

Piezometer #P16 April 12 to 26, 1991



P16

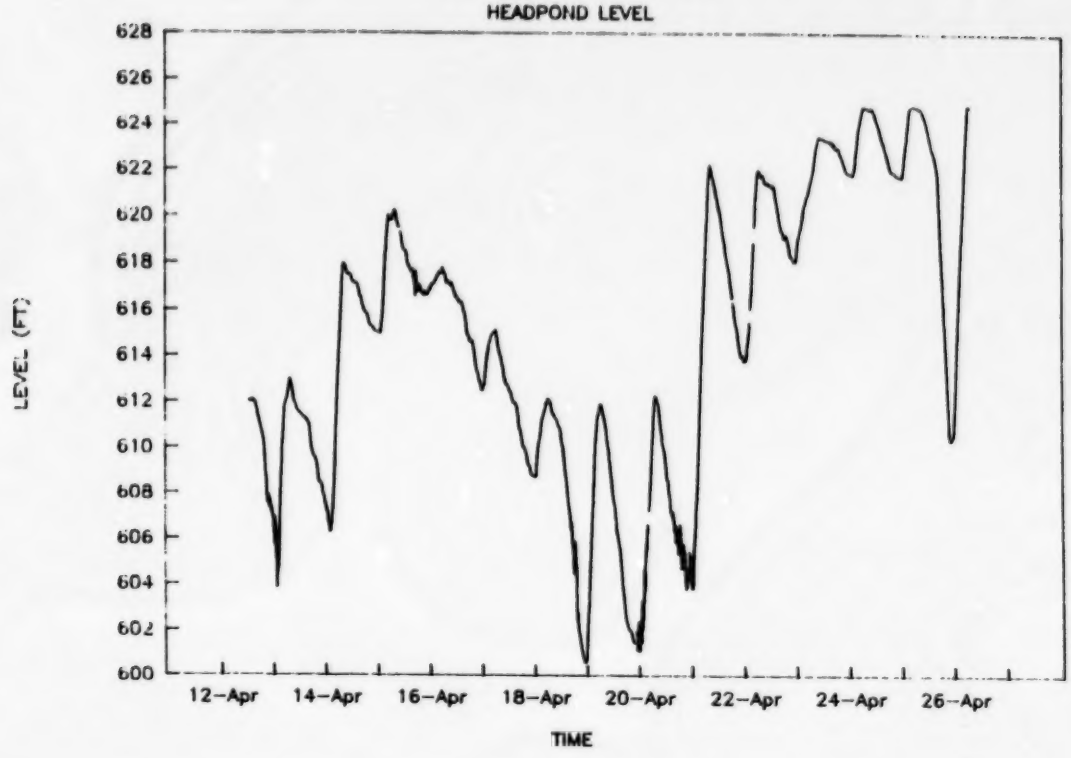

SAB–PGS DYKE
HEADPOND LEVEL
LEVEL (FT)
628
626
624
622
620
618
616
614
612
610
608
606
604
602
600
12–Apr
14–Apr
16–Apr
18–Apr
20–Apr
22–Apr
24–Apr
26–Apr
TIME


SAB–PGS DYKE
Piezometer #P17 April 12 to 26, 1991
PRESSURE PSI
19
18
17
16
15
14
13
12
12–Apr
14–Apr
16–Apr
18–Apr
20–Apr
22–Apr
24–Apr
26–Apr
TIME
P17

91-133

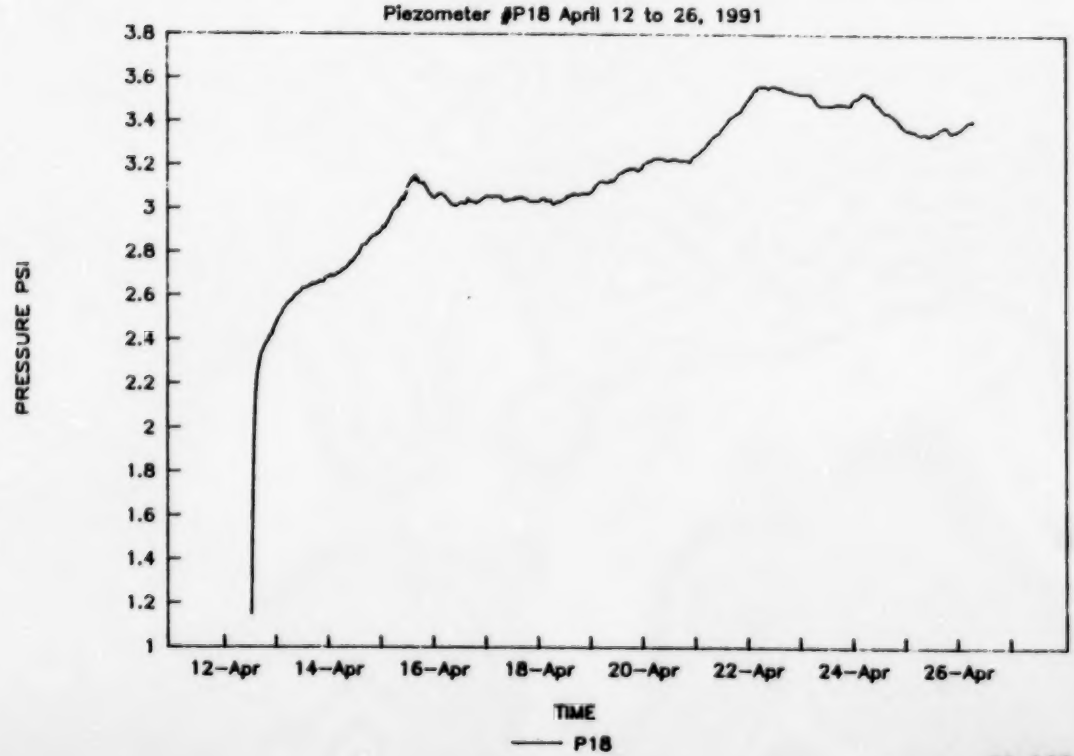
SAB–PGS DYKE

HEADPOND LEVEL



SAB–PGS DYKE

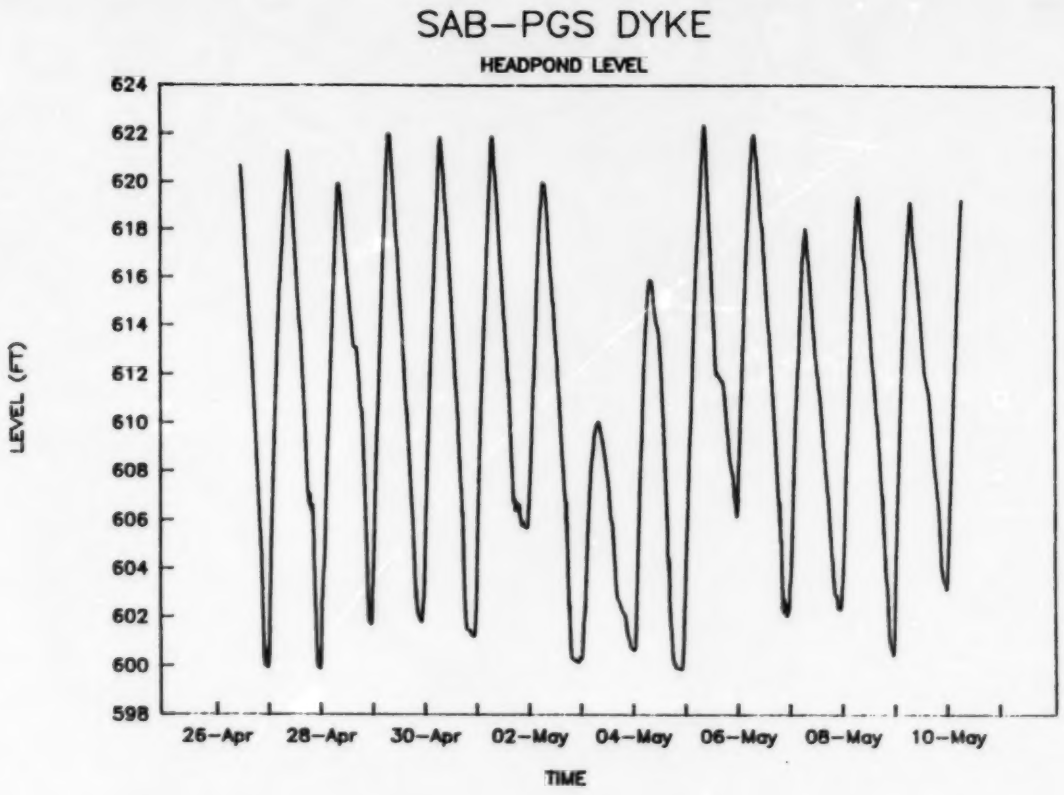
Piezometer #P18 April 12 to 26, 1991

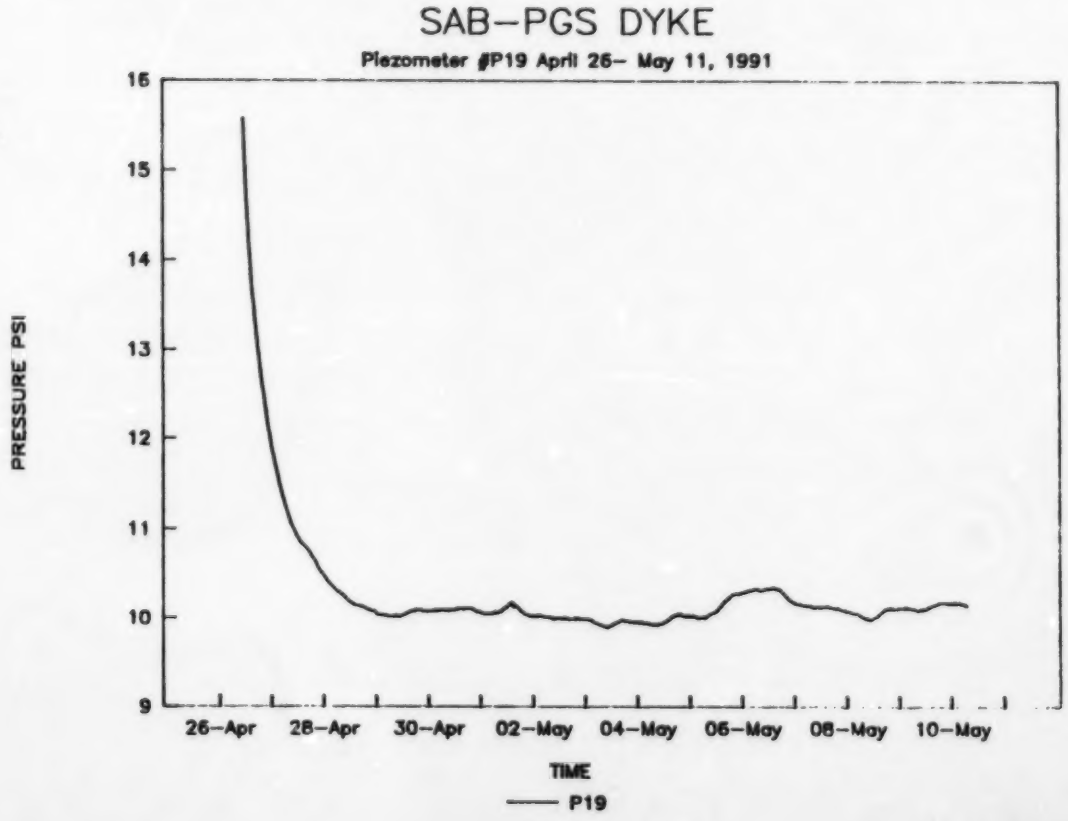


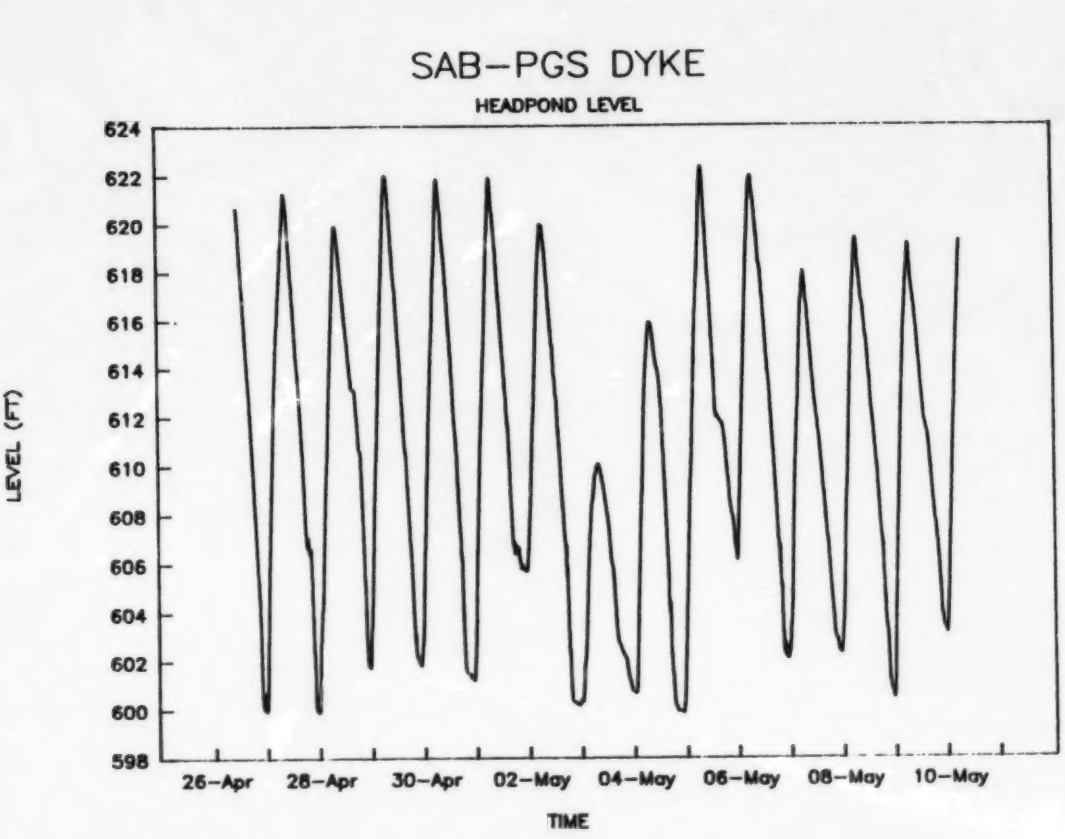
APPENDIX D

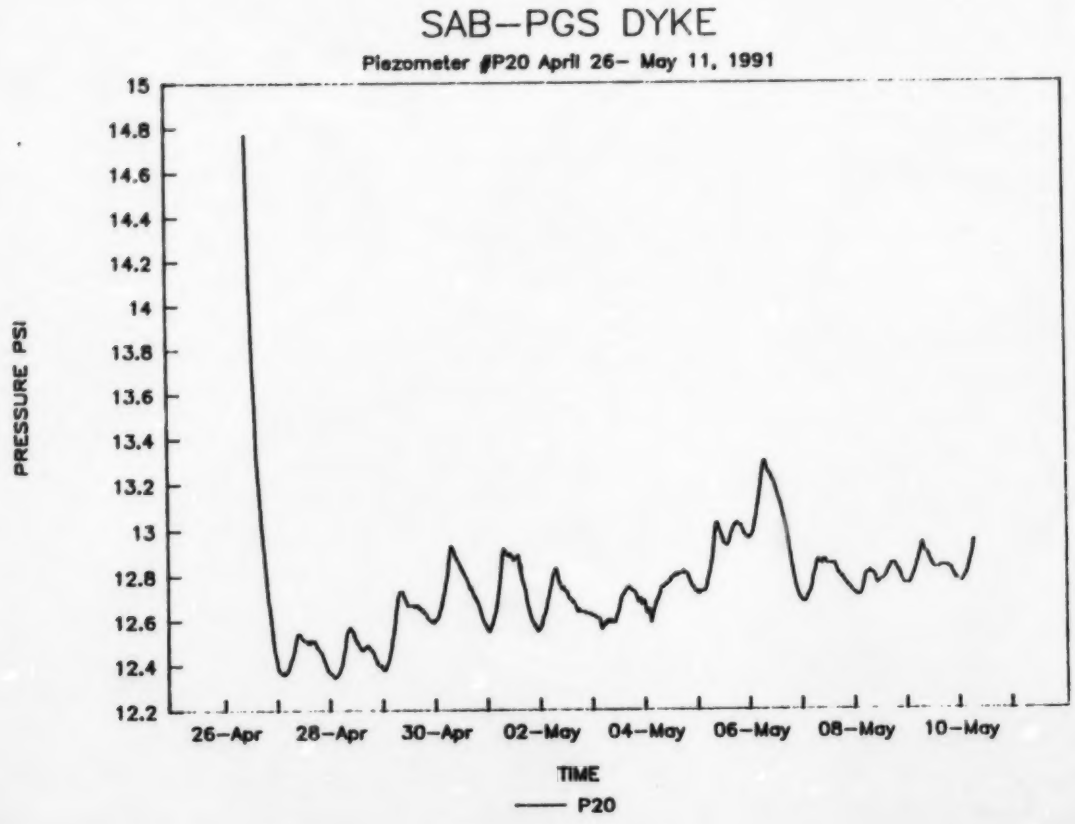
Piezometer #P19 to P22
and
#P2 and P5 (repeated)
April 26 to May 6, 1991

P19 to P22.wk1


SAB–PGS DYKE
HEADPOND LEVEL
LEVEL (FT)
624
622
620
618
616
614
612
610
608
606
604
602
600
598
26–Apr
28–Apr
30–Apr
02–May
04–May
06–May
08–May
10–May
TIME

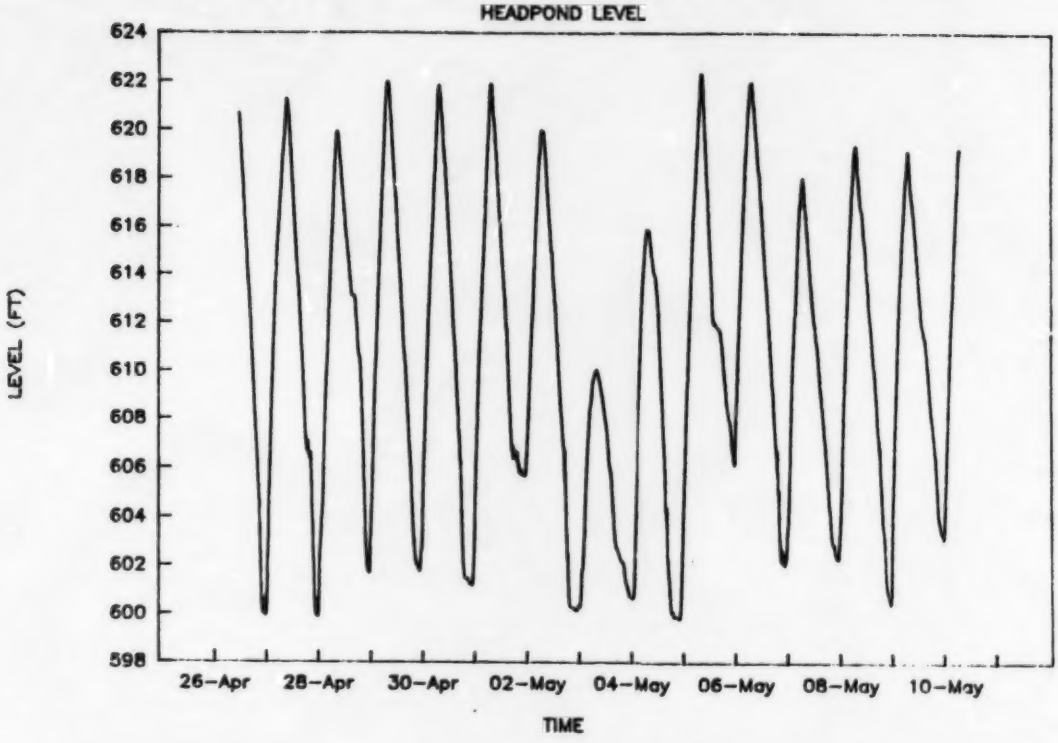

SAB–PGS DYKE
Piezometer #P19 April 26– May 11, 1991
PRESSURE PSI
16
15
14
13
12
11
10
9
26–Apr
28–Apr
30–Apr
02–May
04–May
06–May
08–May
10–May
TIME
P19


SAB–PGS DYKE
HEADPOND LEVEL
LEVEL (FT)
624
622
620
618
616
614
612
610
608
606
604
602
600
598
26–Apr
28–Apr
30–Apr
02–May
04–May
06–May
08–May
10–May
TIME


SAB–PGS DYKE
Piezometer #P20 April 26– May 11, 1991
PRESSURE PSI
15
14.8
14.6
14.4
14.2
14
13.8
13.6
13.4
13.2
13
12.8
12.6
12.4
12.2
26–Apr
28–Apr
30–Apr
02–May
04–May
06–May
08–May
10–May
TIME
P20

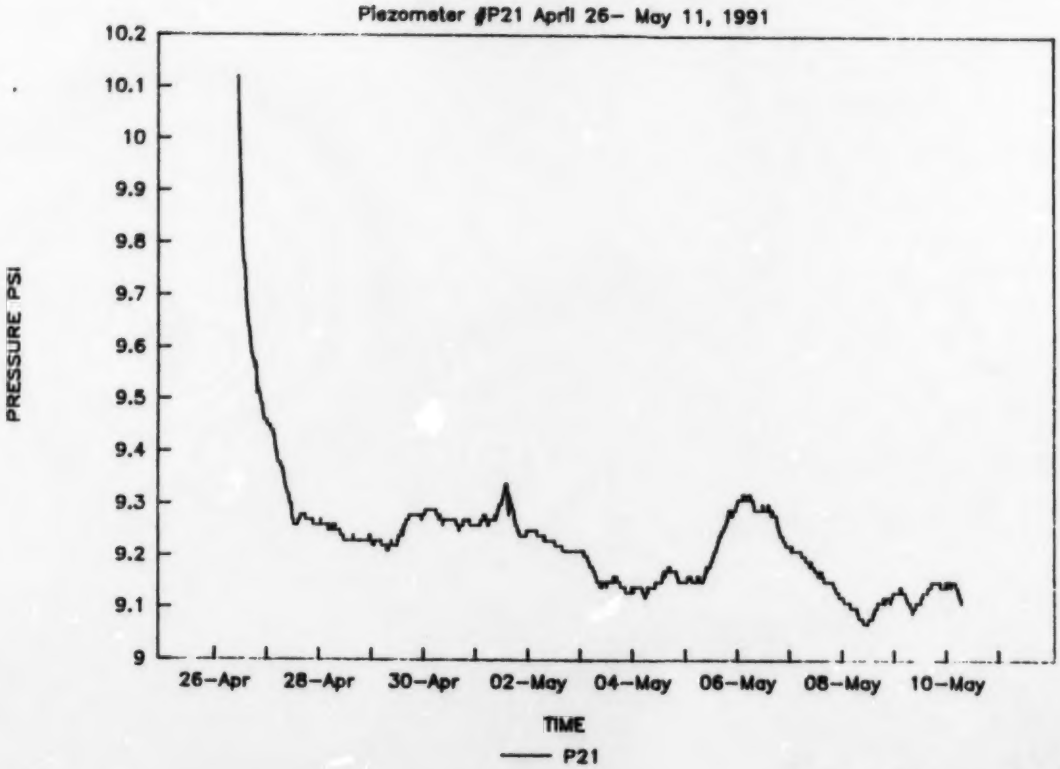
SAB–PGS DYKE

HEADPOND LEVEL



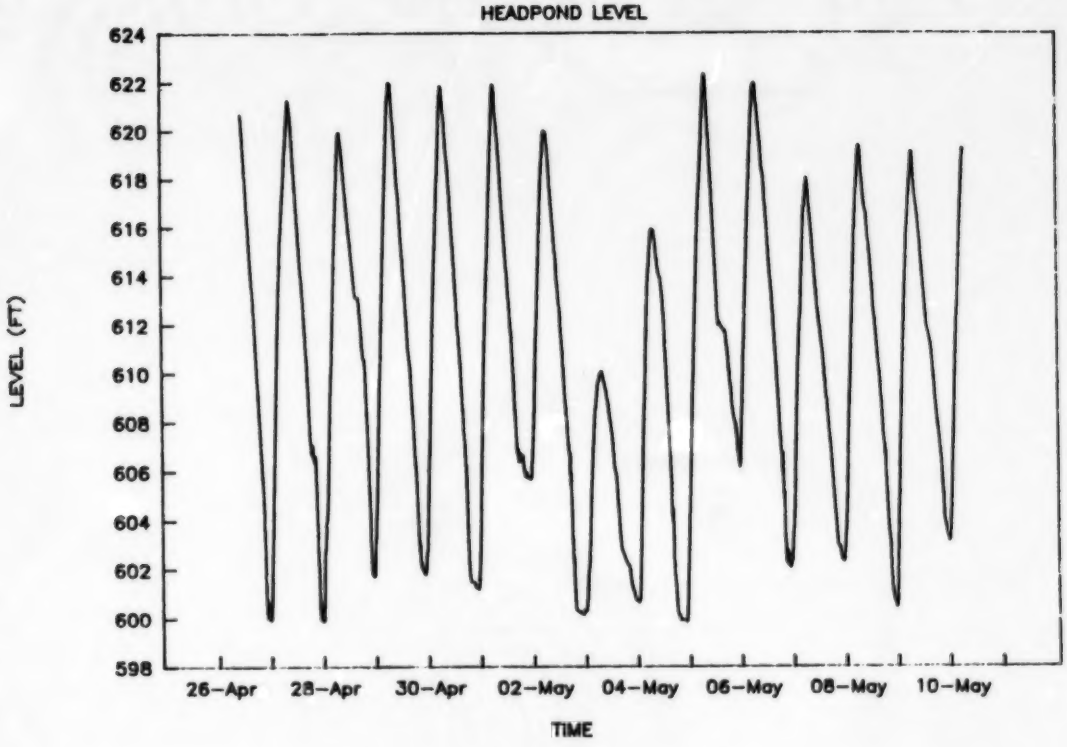
SAB–PGS DYKE

Piezometer #P21 April 26– May 11, 1991



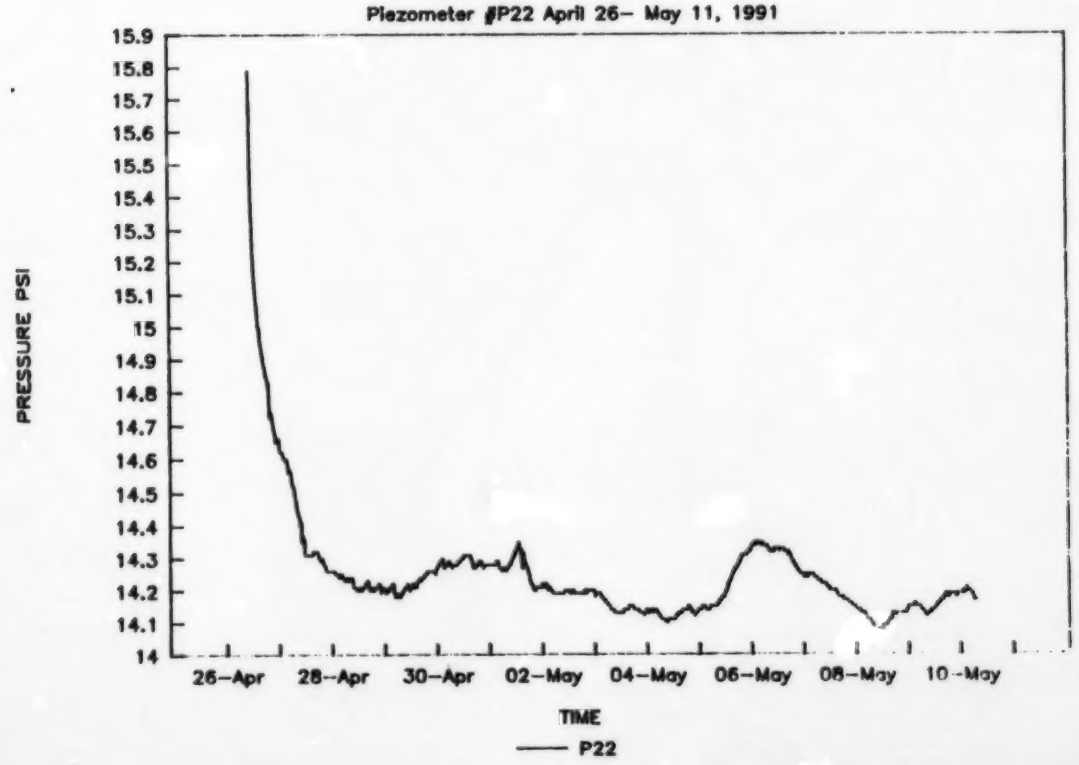
SAB–PGS DYKE

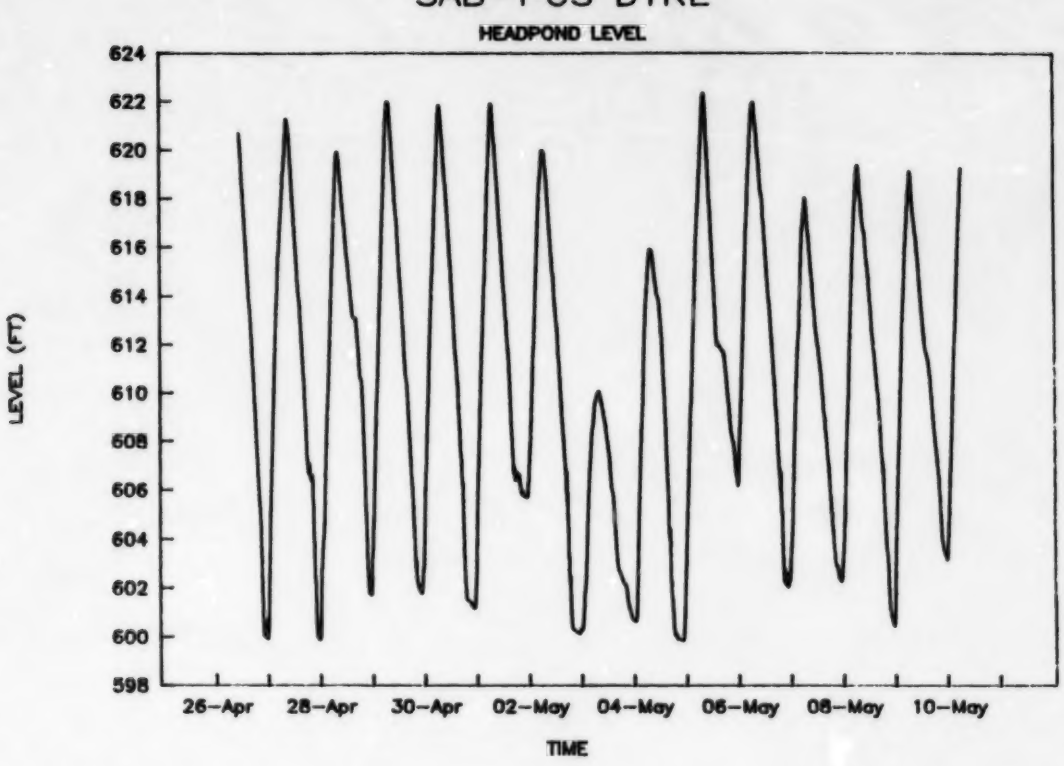
HEADPOND LEVEL

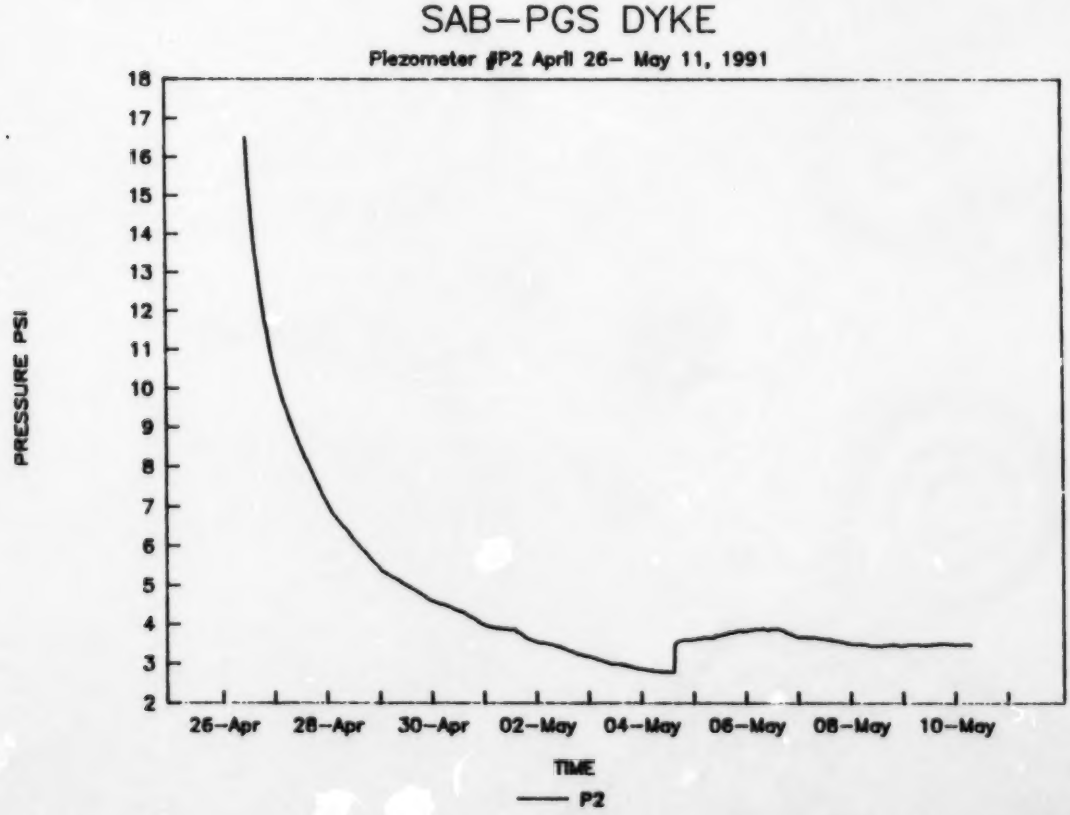


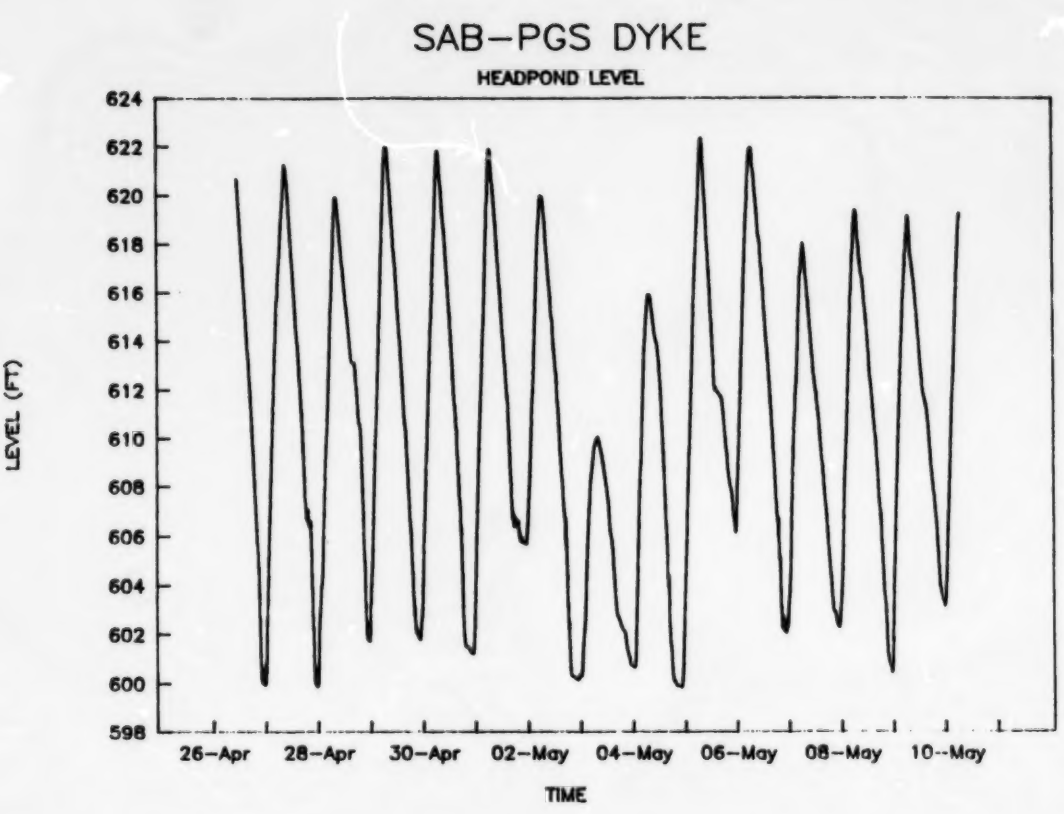
SAB–PGS DYKE

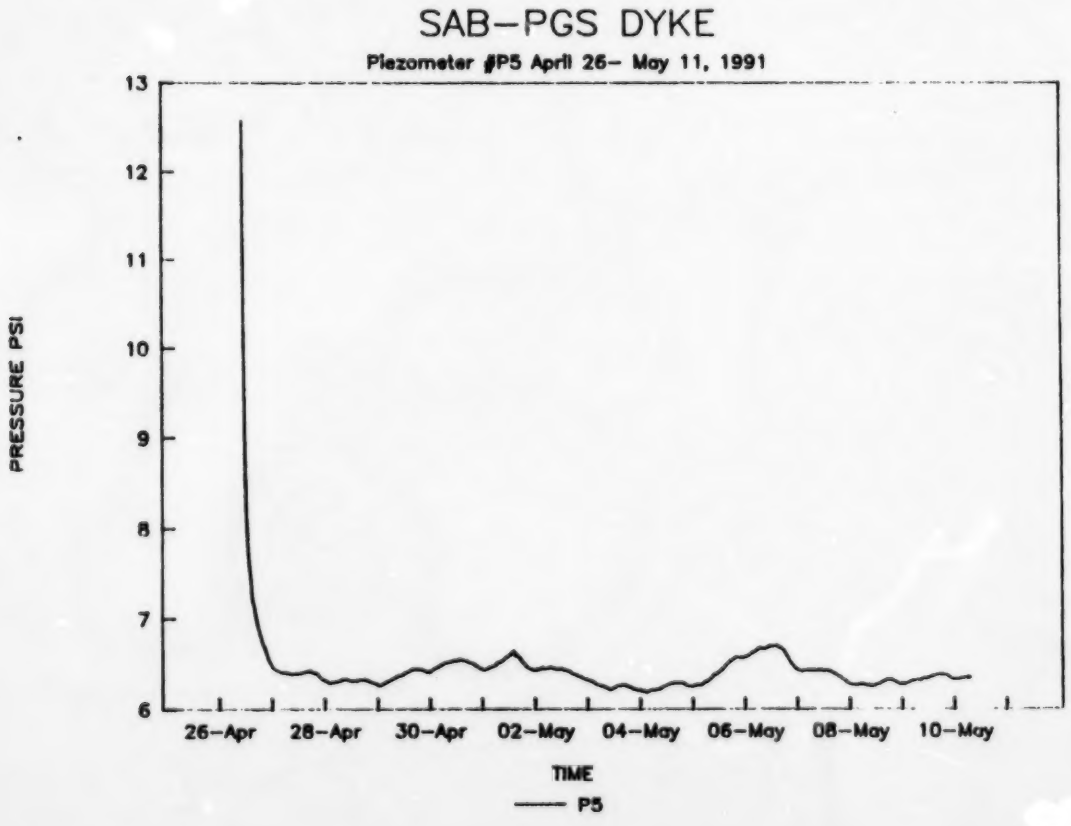
Piezometer #P22 April 26– May 11, 1991




SAB–PGS DYKE
HEADPOND LEVEL
LEVEL (FT)
624
622
620
618
616
614
612
610
608
606
604
602
600
598
26–Apr
28–Apr
30–Apr
02–May
04–May
06–May
08–May
10–May
TIME


SAB–PGS DYKE
Piezometer #P2 April 26– May 11, 1991
PRESSURE PSI
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
26–Apr
28–Apr
30–Apr
02–May
04–May
06–May
08–May
10–May
TIME
P2


SAB–PGS DYKE
HEADPOND LEVEL
LEVEL (FT)
624
622
620
618
616
614
612
610
608
606
604
602
600
598
26–Apr
28–Apr
30–Apr
02–May
04–May
06–May
08–May
10–May
TIME


SAB–PGS DYKE
Piezometer #P5 April 26– May 11, 1991
PRESSURE PSI
13
12
11
10
9
8
7
6
26–Apr
28–Apr
30–Apr
02–May
04–May
06–May
08–May
10–May
TIME
P5